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Valuing Reductions in Risks
A Review of the Empirical Estimates

Energy and Resource Consultants, Inc.
Boulder, CO

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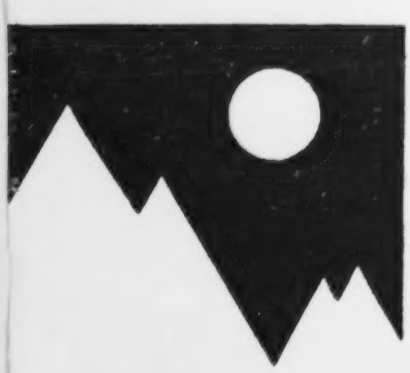

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This report assembles information on estimates of the willingness to pay for changes in health risks. The goal of this review is to provide enough detail on how each study was conducted to allow the reader to have a true feel for the different willingness-to-pay estimates and their applicability to different policy questions. Other reviews do not give the range of estimates found by each study as well as the authors' rationale for selecting one estimate as better than another. The qualifications that the authors present, along with their estimates and the context in which they are estimated, are important for interpreting the policy usefulness of these numbers. Most reviews give these considerations a very cursory treatment and when the estimates actually appear in policy assessments, the qualifications tend to disappear entirely. The result has been inappropriate application of the estimates and, even where applied properly, the level of confidence policy makers should have in the numbers has generally been left unstated. The purpose of this document is to compile the available empirical estimates and documentation in one reference source, present a critical discussion of the estimates, and discuss their usefulness in policy assessment. Many questions are raised for which adequate empirical studies are not available, but which point to useful avenues for future research.

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VALUING REDUCTIONS IN RISKS:
A REVIEW OF THE EMPIRICAL ESTIMATES

Prepared for:

Economic Analysis Division
U.S. Environmental Protection Agency

Prepared by:

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June 1983

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Responsibility for remaining errors and omissions rests, of course, with the authors.

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1.0 INTRODUCTION

Many of the programs and policies that are under development by the U.S. Environmental Protection Agency will influence the level of health risks faced by individuals. Executive Order 12291 requires that the potential benefits of a major regulation be shown to outweigh the potential costs before it is adopted. Assessing the benefits and costs of changes in health risks associated with a regulatory action poses many difficult problems.

The purpose of this report is to assemble the available information on estimates of the willingness to pay for changes in health risks. This review attempts to provide more information on individual studies than has been presented in recent reviews, which primarily list the available estimates with only limited comments.* The goal of this review is to provide enough detail on how each study was conducted to allow the reader to have a true feel for the different willingness-to-pay estimates and their applicability to different policy questions. At present, there is no review that presents the range of estimates found by each study as well as the authors' rationale for selecting one estimate as better than another. The qualifications that the authors present along with their estimates and the context in which they are estimated are important for interpreting the policy usefulness of these numbers. Most reviews give these considerations a very cursory treatment and when the estimates actually appear in policy assessments, the qualifications tend to disappear entirely. The result has been inappropriate application of the estimates and, even where applied properly, the level of confidence policy makers should have in the numbers has generally been left unstated. The purpose of this document is to compile the available empirical estimates and documentation in one reference source, present a critical discussion of the estimates, and discuss their usefulness in policy assessment. Many questions are raised for which adequate empirical studies are not available, but which point to useful avenues for future research.

The scope of this review is, of course, limited by funding and time constraints. The review focuses only on willingness-to-pay (WTP) and willingness-to-accept-compensation (WTA) estimates for valuing changes in risks. Other valuation approaches have been used including estimates of future earnings that would be lost due to an increase in deaths or illness and estimates of medical expenses associated with an increase in illness and death. Although providing useful benchmarks, these approaches do not provide estimates of the benefits to the individual of reducing or preventing health risks because they do not reflect the change in utility, or well-being, that would result from the change in risk of illness or death.* WTP and WTA measures reflect how much of other goods and services the individual is willing to give up in order to obtain a reduction or prevent an increase in health risks. This, therefore, gives a dollar measure of the change in well-being that the individual has or expects to experience. Summing this measure of individual benefits across all affected individuals provides one component of a benefit-cost analysis.

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* Recent reviews include Bailey (1979), Butcher (1981) and Blomquist (1982).

Risks of fatalities, rather than nonfatal injuries or illnesses, are emphasized in this review. This should not be construed as implying that risks of morbidity are not an important consideration for environmental policy questions, because they are very important. This emphasis merely reflects the fact that most empirical estimates of the value of life and safety have used mortality data. The many facets of morbidity have not made it conducive to empirical work.

Throughout this report, the results of the different studies are compared by reference to the estimated value of life or value per life saved. The reader should be aware that this is not meant to be thought of as an amount of money that an individual would accept in exchange for his or her life. This is rather a way of comparing valuations for small reductions in risks that affect a large number of people. For example, say a certain environmental policy decision will reduce the risk of death from exposure to a given toxic substance from 1 out of 100,000 to 1 out of 200,000 for a total of 1,000,000 people. Each individual's probability of death from this cause will be reduced from 10^{-5} to 5×10^{-6}, a change of 5×10^{-6}. If every individual is willing to pay \$10 for this reduction in the probability of his or her death, then the willingness to pay per life saved is

$$\$10/.000005 = \$2,000,000$$

An alternative derivation of this "value of life" is to look at the number of lives saved. The number of deaths out of the 1,000,000 people affected would be reduced from 10 to

---

* Butcher (1981) and Bailey (1979) discuss this in more detail.

5. For these five lives each individual in the group would be willing to pay $10. Thus the total value per life saved would be:

$$\$10 \times 1{,}000{,}000/5 = \$2{,}000{,}000.$$

We apologize in advance to any authors whose work may be relevant but omitted from this document. Simply reading all of the potentially relevant reserach work would have exhausted the project funds. A common response of reviewers to the draft version of the report was to list 10 to 15 potentially relevant articles that we had not incorporated. Of course, it was not possible to include all of the helpful suggestions. We feel that we have included the major empirical results, but work on related theoretic issues was included on a very selective basis. A major line of research that was omitted concerns the relationship between the "value of life" and human capital expressed largely by one's lifetime earnings and activities. Selected contributions include Usher (1973), Conley (1976), Jones-Lee (1978 and 1980), Linnerooth (1979) and Arthur (1981). The focus of this work has been on identifying when a person's human capital, based on lifetime earnings and consumption, can be viewed as a lower bound to the value placed on his/her life on purely theoretical grounds. Mishan (1982) points out that the conclusions to these models remain unvalidated until we have direct estimates of the "value of a life." Once the estimates are obtained, these models become superfluous for policy making. In any event, since these articles did not present empirical results and since the large amount of work on this topic could not be easily reviewed or condensed, they were reluctantly excluded from this document.

The studies reviewed in this report are grouped into three categories. Chapter 2 covers hedonic wage-risk studies that look at tradeoffs between on-the-job risks and wages. Chapter 3 includes consumer market studies that examine consumption and activity choices that people make that affect their safety. Chapter 4 covers contingent market studies that use surveys that ask people how much they value increases in safety or improvements in health. Chapter 5 discusses estimation issues that are of concern for policy questions related to environmental health and safety, but that have not been addressed in these empirical studies. Chapter 6 summarizes the conclusions of the report and provides suggestions for future research.

2.0 RISK VALUATION USING WAGE STUDIES

This section examines empirical estimates of the value of life and safety that have been based on observations of transactions that take place in the labor market. These studies have found a consistently positive and statistically significant wage premium that is attributed to risks of injury (potentially fatal) on the job. This Chapter presents briefly the economic theory upon which these studies are based. Then, each study is reviewed in considerable detail and issues are raised concerning the applicability of these results to environmental policy decisions.

2.1 A SIMPLE MODEL

Following Rosen (1981) and Freeman (1979b), this section shows how willingness to pay can be inferred from market transactions. The simplest model is a one period model where utility is dependent upon surviving the single period, and there is no value associated with legacies left to the individual's heirs and, therefore, no need for insurance. Utility conditional on survival is expressed as $U(C)$ where C is consumption. Let the probability of surviving be r, then expected utility EU is $rU(C)$. Starting with initial risk and consumption levels of r^o and C^o, then the individual can rearrange his levels of consumption and risk. It is possible that higher levels of utility can be achieved with different consumption and risk combinations. This formulation assumes that the individual has an accurate perception of the risks that he faces and the alternatives he has for reducing or increasing those risks. The individual's decision can be expressed as follows:

$$\max EU = rU(C)$$

$$\text{subject to: } P_c C^o + P_r r^o - P_c C - P_r r = 0;$$

where P_c is the price of the composite consumption commodity and P_r is the price at which consumption can be traded for increased probabilities of survival.

A first order condition for maximization of expected utility is:

$$P_r = P_c \left(\frac{U(C)}{rU'(C)} \right) \qquad \text{Eq. 1}$$

where the term $U(C)/rU'(C)$ is the marginal rate of substitution between consumption and risk.* The individual can achieve this maximum by shifting expenditures between consumption and higher probabilities of survival. Equation 1 allows inferences regarding the individual's willingness to pay for marginal change in risk. The willingness to pay is simply the right-hand side of Equation 1.

This formulation can be extended to consider different sources of risk. Freeman (1979) considers three types of risk: random risks, consumptive risks and occupational risks. Random risks are the result of factors beyond the control of any individual. These would include factors such as unpredictable accidents, diseases due to aging, or exposures to environmental pollutants. Consumptive risks are risks associated with consumption activities. Individuals can change their consumptive risks by their choice of activities. Occupational risk stems from hazards associated with the work place.

This division of risks allows the formulation of the following individual choice problem:

$$\max EU = rU(C_1, ..., C_n)$$

$$\text{subject to: } W(M_w) - \sum_{i=1}^{n} P_i C_i$$

where: P_i = price of C_i

C_i = the i^{th} consumption activity

$W(M_w)$ = the wage rate dependent upon the occupational risk M_w.

$r = 1 - M_i - M_w + M_i M_w$

M_i = the risk of death associated with the i^{th} consumption activity

---

* This can be shown by taking the total derivative of expected utility $EU = rU(C)$.

The first order conditions for a maximum show:

$$\frac{W}{M_w} = P_i \left(\frac{U(C)}{r\ \partial U(C) / \partial C_i} \right) \qquad \text{Eq. 2}$$

The right hand side of the equation is simply the marginal willingness to trade consumption of good C_i for changes in risk.* If wages as a function of risk are known, then the marginal wage premium required as compensation for risk, $\partial W / \partial M_w$, can be taken as an estimate of the individual's willingness to pay for marginal changes in risk. This has been the basis of much of the empirical work on willingness to pay for marginal changes in risk.**

2.2 HEDONIC WAGE-RISK STUDIES — INTRODUCTORY DISCUSSION

Hedonic price theory views a market good as being a bundle of attributes that can occur in various combinations and quantities. The price that the consumer is willing to pay for such a good is a reflection of the sum of the utility expected to be derived from the attributes. The labor market can be viewed from this perspective. The worker supplies his labor for a job that can be described by a set of job characteristics, or attributes, in exchange for a wage. These job characteristics include such things as job safety, type of work, location and physical environment. At the same time, the employer is willing to offer a certain wage in exchange for having this job done. This interaction between the employers and the workers maps out a set of market equilibrium wages that are paid or accepted for specific jobs reflecting the associated job characteristics. In the case of risks of accidents and illnesses resulting from work activites, we can expect a tradeoff between the wage rates that workers will accept and the risks they expect to encounter. Also, there is a tradeoff between the measures an employer is willing to take to make the job safer and the wage he must pay to attract workers. If wages are positively

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* Recall, from the simple model that U(C) divided by rU'(C) is the marginal rate of substitution between risk and consumption.

** Freeman's formulation ignores the differences between willingness-to-pay for a reduction in risk and willingness-to-accept compensation for an increase in risk. Theoretically, these differences are not expected to be large. See Freeman (1979b, p. 47-48) for his discussion on this.

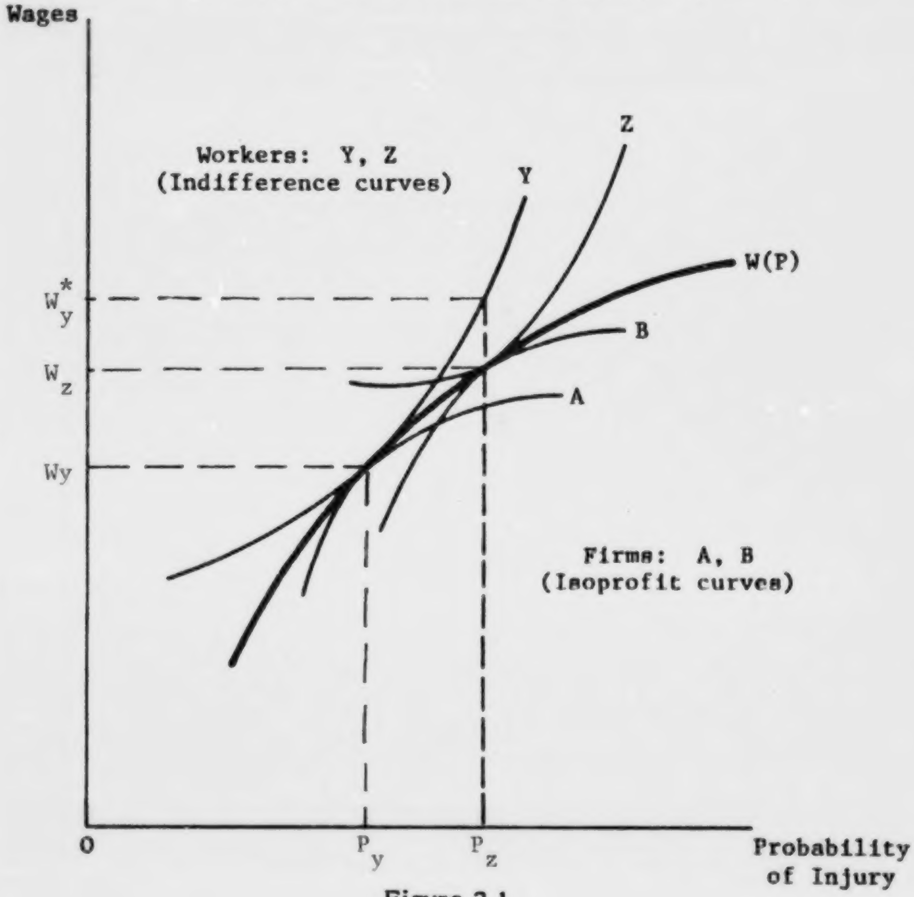
Wages
Workers: Y, Z
(Indifference curves)
Z
Y
W(P)
W_y^*
B
W_z
A
Wy
Firms: A, B
(Isoprofit curves)
0
P_y
P_z
Probability of Injury

Figure 2.1
Market Equilibrium

Source: Butcher 1981

related to job risks, then the employer can implement additional safety measures in return for a lower wage-risk premium required by workers. In theory, the employer will undertake safety improvements up to the point where the marginal cost of increasing job safety equals the marginal reduction in wage cost resulting from a lower risk premium being demanded by workers. The worker's position will be influenced by his skills in protecting himself, his aversion to risk and other socioeconomic characteristics. The employer's position will be influenced by his production technology and the costs and benefits to him of providing increased safety on this particular job.

This market equilibrium between workers and employers establishes the risk premium that is being paid to workers. This is illustrated in Figure 2.1. A and B are isoprofit curves for two different firms and Y and Z are indifferences curves for two different workers. The tangencies of these map out W(P), a function that shows how wages change with increases in risks of injury on the job. It is this equilibrium tangency that is observed on the market. This will give one point on each worker's indifference curve. In other words, the wage at which the worker is observed represents one point on his willingness-to-accept compensation for encountering increased risks of injury, but W(P) does not map out the individual's tradeoff for all levels of risks. It is the market equilibrium resulting from the interaction of workers and employers. W(P) is referred to as the hedonic price function for risk because it shows the market established tradeoff between wages and risks. *

Hedonic Estimation Assumptions

The estimation procedure used to identify the tradeoff between wages and job characteristics is to take wages as a function of job characteristics and see how changes in job risks affect market determined wages. Market equilibrium will occur where each worker is maximizing his utility with the wage-risk tradeoff that he accepts; therefore, the point at which he is observed will reflect the marginal valuation he would put on a marginal change in risk, holding all else constant. In order for this marginal valuation of risk to be reflected in market conditions as has been described, certain assumptions must be met. Two of the most problematic are (1) that the labor market operates freely and is in equilibrium, and (2) that workers are aware of the risks associated with different jobs that they might consider.

If the first assumption is violated, the estimated valuation can be biased. If, for example, a universal improvement in safety equipment has occurred and wage markets have not yet adjusted, observed risk premiums may be biased upward because they are still reflecting the higher level of risk. Slow adjustments will not introduce bias if changes in

---

* It is possible that individuals at the lower end of W(P) will be more risk averse than those at the upper end.

safety have occurred in both directions--better equipment introduced in one place and a more dangerous procedure in another. These reviewers are not aware of any empirical evidence concerning the speed and nature of these kinds of labor market adjustments.

Union bargaining power may also push risk premiums higher than they would be under competitive equilibrium conditions. Several authors (Olson, 1981; Thaler and Rosen, 1975; V. K. Smith, 1982) have found a positive and statistically significant interaction between union membership and wage-risk premiums. Union members are observed to receive greater compensation for incurring risk than nonunion workers. A variety of explanations could account for this, each requiring empirical verification along some other avenue. Whatever the correct explanation, it is doubtful whether, based on this evidence, the EPA would want to conclude that union workers are more risk averse than nonunion workers or that the benefits of protecting union workers are greater than protecting nonunion workers.

The assumption that workers are aware of the risks associated with different jobs is necessary in order for observed wage-risk premiums to be an accurate reflection of the amount of compensation that would be required to induce the individual to accept such a risk. Misperceptions that are random will increase the standard errors of the estimated wage-risk premiums but the estimate will be biased only if there is some systematic pattern in the misperceptions. Very little is known about the factors that may influence a person's perceptions of risk. Lichtenstein et al. (1978) found that there was some systematic error in what people thought to be the frequency of lethal events. Some empirical work in the form of surveys concerning perceived injury rates could be very helpful in terms of establishing the validity of wage-risk studies for quantifying risk premiums. Evidence that people are aware of making these tradeoffs would support the conclusion that the observed correlation between wages and job risks is truly a measure of people's willingness-to-accept dollar compensation in order to incur additional risk. Other issues related to accurate risk perception (i.e., the preference reversal phenomenon and cognitive dissonance) are discussed in Chapter 5.

2.3 REVIEWS OF THE WAGE-RISK STUDIES

Seven wage-risk studies are reviewed in this section. All of them use some variation of the theoretical framework that was introduced above and face similar kinds of problems. The review will consider the injury data used, the population group for which risk premiums were estimated, and specific assumptions and procedures unique to each study.

The authors of these studies are aware of the potential policy applications of their results, but the focus of these studies has been on testing whether the labor market functions as is theorized. In this sense, they are concerned more with accurate characterizations of the labor market than with the applicability of their estimates to policy questions.

2.3.1 Robert S. Smith (1974 and 1976)

R. Smith (1974, 1976) developed a model to estimate the incremental costs of worker injuries to the firm in order to calculate what injury fine would be necessary to encourage firms to reduce injuries. He considers injury costs in terms of wage premiums required by workers exposed to risks of injury and costs such as equipment damage, training, and lost production. His results indicate that a ten percent reduction in occupational injuries would require a fine of $1,600 to $3,100 (1967 dollars) per injury. Although Smith's model was designed to estimate the effects of different injury taxes, a crucial component of the model was the estimation of the wage compensation required by different levels of job injury risks. This portion of the model is the focus of this review.

Estimation Model.

The model used by R. Smith (1974, 1976) utilizes the assumption that, in the absence of full ex post compensation for injuries, workers require ex ante compensation in the form of wage premiums. The equilibrium condition across industries is then:

$$W_{ij} - E(L_{ij}) = W^n(H_j,Z_j) \text{Eq. 3}$$

where:

W_{ij} = the gross wage of the i^{th} worker in the j^{th} class of workers

$E(L_{ij})$ = the worker's expected uncompensated losses from injury

W^n = net wage as a function of human capital H_j and other variables Z_j.

The workers' expected uncompensated losses, $E(L_{ij})$, were assumed to be the expected losses of three types of injuries: death (d), permanent impairment (p), and temporary disability (t). The risk, or likelihood, of being killed is $a \cdot R^d$ where "a" is the hourly injury rate for all injuries and R^d is the fraction of injuries resulting in death. The model assumes that the uncompensated losses associated with death are proportional to the wage rate, i.e., losses associated with death are $b_d W$ where b_d is a constant. Similarly, $b_p W$ represents losses associated with a permanent impairment and $b_t W$ represents losses associated with a temporary impairment. Using these definitions, Equation 3 becomes:

$$W_{ij} - a_{ij} (b_d W_{ij} R^d_{ij} + b_p W_{ij} R^p_{ij} + b_t W_{ij} R^t_{ij}) = W^n(H_j,Z_j),$$

which reduces to:

$$W_{ij} \left[1 - b_d (R^d_{ij} a_{ij}) - b_p (R^p_{ij} a_{ij}) - b_t (R^t_{ij} a_{ij}) \right] = W^n (H_j,Z_j).$$

To put this in a linear form suitable for estimation, R. Smith uses the approximation $\ln (1 + X) = X$. He feels this is appropriate as long as the expected uncompensated losses from injury are less than 50 percent of gross wages. This approximation yields the following equation for estimation:

$$\ln W_{ij} = b_d R^d_{ij} a_{ij} + b_p R^p_{ij} a_{ij} + b_t R^t_{ij} a_{ij} + \ln W^n(H_j,Z_j) \qquad \text{Eq. 4}$$

The coefficients to be estimated are then b_d, b_p, and b_t. Recall that these values correspond to the proportion of the wage rate W_{ij} that comprises the expected loss due to injury that must be compensated by the payment of a higher wage. In his empirical estimate, Smith uses injury rates per 10^6 man hours of work, so b_d, b_p, and b_t can be interpreted as the wage premiums required by the workers for an increase in the risk of injury corresponding to one additional injury per 10^6 man hours of work.

Data Used.

Data on W_{ij}, R_{ij}, a_{ij} and the determinants of $W^n{}_{ij}$ (i.e., the contribution to the wage differential from other nonrisk variables) were obtained from the May 1967 Current Population Survey (U.S. Bureau of the Census) which contained supplemental questions on wage rates and union membership as well as the standard socioeconomic variables. The specification of the independent variables for explaining $W^n(H,Z)$ followed the earlier research performed by Oaxaca (1973) using the same data base. These variables included: education, experience, union membership, class of worker, occupation, demographic characteristics, geographic dummies, migration variables and, in one specification, industrial dummies.

Injury rates were 1966 and 1967 Bureau of Labor Statistics (BLS) injury rates by industry measured as injuries per million hours worked. The probability of injury assigned to each individual was the average for the industry in which he works. The use of industry average data introduces measurement errors into the risk variables, but the lack of injury data cross-tabulated by industry and occupation made this unavoidable.*

This sample included 3,183 white males. In R. Smith (1976), the model was re-estimated with the 1973 Current Population Survey and 1970 Bureau of Labor Statistics injury rates.

Estimation Results.

The estimation results are shown in Table 2.1. Specification II is the same as I except for the inclusion of industry group dummy variables. The two specifications show substantially different estimates. The results of the two specifications suggest the presence of

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* We are not aware of evidence about the magnitude of this measurement error. Thaler and Rosen (1975) suggest that it might be quite large.

Table 2.1

Estimates of Wage Equation, from R. Smith (1974)
Dependent Variable = ln(WAGE)

Independent Variables	Specification I	Specification II
Constant	−.158 (−2.50)	−.232 (−3.54)
Education	.046 (16.02)	.045 (15.51)
Experience	.018 (9.31)	.017 (9.08)
Experience^2	$-.026 \times 10^{-2}$ (−6.97)	$-.025 \times 10^{-2}$ (−6.88)
Union	.102 (6.63)	.098 (6.36)
Deaths per 10^6 man-hours b_d	1.238 (6.97)	.636 (2.40)
Permanent impairments per 10^6 man-hours b_p	.075 (2.57)	−.033 (−.85)
Temporary impairments per 10^6 man-hours b_t	−.006 (−3.79)	−.002 (−1.31)
Firm size	$-.003 \times 10^{-3}$ (−.09)	$-.016 \times 10^{-3}$ (−.55)
Class of Worker:		
Government	−.103 (−2.63)	−.121 (−3.08)
Self employed	−.123 (−2.34)	−1.20 (−2.29)
Occupation:		
Professional worker	.206 (5.53)	.186 (4.90)
Manager	.175 (4.63)	.190 (5.01)
Clerical	−.048 (−1.21)	−.057 (−1.40)
Craftsmen	.045 (1.31)	.028 (.79)
Operatives	−.081 (−2.36)	−.090 (−2.60)
Service workers	−.218 (−4.82)	−.131 (2.73)
Laborers	−.108 (2.58)	−.115 (−2.73)
Part-time	−.296 (−8.87)	−.269 (−8.05)

Table 2.1, cont.

Demographic Characteristics:		
Health problem	.096 (4.01)	.094 (3.99)
Spouse present	.177 (7.26)	.170 (7.03)
Spouse absent	.224 (1.78)	.199 (1.59)
Widowed	.115 (1.64)	.118 (1.70)
Divorced	.118 (2.61)	.114 (2.55)
Size of Urban Area:		
SMSA < 250,000	.067 (2.67)	.066 (2.64)
SMSA 250-500,000	.111 (4.31)	.097 (3.77)
SMSA 500-750,000	.161 (6.03)	.153 (5.76)
SMSA > 750,000	.172 (8.77)	.167 (8.51)
Region:		
Northeast	.125 (6.35)	.121 (6.19)
North Central	.134 (7.03)	.124 (6.52)
West	.150 (6.73)	.149 (6.72)
Migration:		
Recent migrant	.006 (3.01)	.005 (2.57)
Years since migration	−.0013 (−.66)	−.0008 (−.40)
(Years since migration)^2	$.006 \times 10^{-2}$ (1.39)	$.006 \times 10^{-2}$ (1.26)
Industry:		
Construction	—	.233 (5.03)
Durable manufacturing	—	.193 (5.47)
Non-durable manufacturing	—	.131 (3.96)
Wholesale trade	—	.164 (3.87)
Business and repair services	—	.025 (.47)
Personal services	—	−.174 (−2.49)
R^2	.45	.46
Std. Error of estimate	.370	.366

*t values in parentheses.

compensating wage differentials related to the occupational risks of death, but provide less conclusive evidence regarding the existence of wage differentials due to risks of permanent or temporary injury. This tends to support the hypothesis that where ex post compensation is impossible, as in the case of death, then a compensating wage differential may be necessary to attract workers. For nonfatal accidents, where ex post compensation is possible, the evidence for the existence of wage differentials is mixed. In the first specification, the fatal injury and permanent disability variables had significant and positive coefficients, but the temporary disability variable had a significant negative coefficient. When the industry group dummies were added, both of the coefficients on the nonfatal injuries were seen to be insignificant.

R. Smith (1976) performed another study with the same model but using data from the 1973 Current Population Survey for white males and the 1970 BLS injury rate data. One motivation for this second study was the extreme difference between the R. Smith (1974) and the Thaler and Rosen (1975) estimates. In this second estimation, R. Smith used only workers in manufacturing industries to reduce potential biases from omitted variables related to job disutility or union strength that could be correlated with job safety. For example, the inclusion of coal mining or the construction industries could cause this bias. Several other adjustments were made in the data to obtain more accurate wage data and, because uncompensated losses from nonfatal injuries were expected to be so small as to be undetectable, their effects were constrained to be zero.

The estimated coefficients from the wage equation in this second study were:

	Sample I	Sample II
Risk Variable:		
Deaths per 10^6 manhours	.390	.382

Sample I was comprised of all workers in manufacturing. To verify the results of Sample I, a smaller sample (Sample II), consisting only of hourly workers was used. Sample II is most likely comprised of actual production workers and the hourly wage rate is probably a better estimate of overall earnings.

Table 2.2 presents the four estimates obtained from the two R. Smith (1974, 1976) studies. There is little basis for choosing among these estimates since none of the

Table 2.2

R. Smith (1974 and 1976) Estimates of Willingness-to-Accept Compensation for a Statistical Life

	Mean Risk Level[a]	WTA per Statistical Life[b]
1967 Data		
Specification I	1.5	$\$4.9 \times 10^6$
Specification II[c]	1.5	$\$2.6 \times 10^6$
1973 Data		
Sample I	1.5	1.6×10^6
Sample II[d]	1.5	1.5×10^6

[a] 1.5 deaths per 10,000 workers per year. This was not reported by this author but taken from another study that used the same data set.

[b] The value of a statistical life--coefficient on risk x mean hourly wages x 10^6.

[c] Uses industry dummy variable.

[d] Sample comprised of hourly workers only.

different estimation results is clearly superior to the others. The author does suggest, however, that the 1973 estimates may be preferable because the narrower sample of workers used (manufacturing only) could be expected to reduce the risk of unspecified differences across industries confounding the estimation of the wage-risk premium.

Comments

The model and estimation procedure were straightforward. The principal question that arises from Smith's model is why the addition of industry dummies changed the estimated coefficients on nonfatal injuries so substantially. Since only the average risk level for each industry was used as a proxy for each individual's risk, the risk variable for all individuals in a particular industry would be the same. By adding intercept dummy variables for industry groups which are also constants, it is likely that the risk variable and the industry group variable would be correlated. The large t-values tend to show the usefulness of the industry dummies, in terms of capturing factors that vary across industry groups but which are omitted from the specification. Still, it may be possible that the coefficients on the dummy variables are capturing at least part of the wage differential due to risk variation across industries. Given this information, it is not clear which of the estimates of wage premiums, Specification I or Specification II, is in any way superior.

A second issue raised by Smith's work is whether wage rate studies will be useful for estimating the willingness-to-accept compensation for risks that can be compensated ex post by employers. These include nonfatal accidents where worker's compensation and employee insurance may largely account for the expected loss and no wage premium is required. Smith's results indicate that wage-risk studies may not be useful for estimating willingness-to-accept compensation for nonfatal injuries.

2.3.2 R. Thaler and S. Rosen (1975)

These authors apply the hedonic theory developed by Rosen (1974) in order to estimate the compensation required to induce workers to take risky jobs. They develop the theory underlying the behavior of employer and employee wage-risk tradeoffs, and the resulting interaction that creates a market equilibrium between wages and risk.

Data Used.

Risks of death were obtained from the 1967 Occupation Study by the Society of Actuaries. This study provided data on actual deaths per hundred thousand policy years associated with some very hazardous occupations. These data were tabulated on an occupational basis. From this data, Thaler and Rosen calculated a variable called extra deaths per hundred thousand policy years by subtracting average expected deaths for the general population. This was done using the age distribution of persons in the sample and standard life tables. The result of this subtraction is extra or excess deaths above the national average associated with different occupations. The results of this are shown in Table 2.3.

Thaler and Rosen claim that the use of these occupational risk data is superior to the BLS injury indices available by industry that were used by R. Smith (1974). The use of industry average risk data "introduces a huge component of measurement error for individuals, because job risks in each industry are not uniform across occupations" (Thaler and Rosen, p. 286). Thaler and Rosen admit that some measurement errors still exist in their data set since the occupational classifications are still quite broad, but they assert that the degree of measurement error in their risk estimates is "perhaps as much as an order of magnitude smaller."

While their occupational risk data have some desirable attributes, the particular data set used by Thaler and Rosen contains some potential problems that were not discussed in their paper. Lipsey (1975) points out that their risk data actually measure something other than occupational risk. The risk they are measuring is the extra risk to the insurance company of insuring those who are in a particular occupation. Some of the surprises in Table 2.3 illustrate this potential problem. For example, elevator operators, bartenders and waiters are listed as having far more risky occupations than being employed as a policeman, detective, or fireman. Lipsey points out that insurance risk will encompass both true occupational risk and risk associated with personal characteristics. Using Lipsey's example, people attracted to bartending may have personal habits or characteristics which increase their insurable risk independent of which occupation they were to enter. Since these personal characteristics are attached to the individual rather than associated with the job, there will be no positive compensating wage differential. In fact, these characteristics could have the opposite effect, i.e., result in lower wages for these occupations. Having individuals as employees who are more likely to incur injuries increases the cost of doing business. This would result in lower productivity and, therefore, lower wages being offered to these individuals. Thaler and Rosen may have reduced one source of measurement error in their risk data only to add another source of measurement error of an unknown magnitude.

Even if the authors' occupational risk data were entirely accurate, it is questionable that it would match the perceptions of individuals in the labor market who are negotiating their wage-risk premiums. Table 2.3 shows an ordering of occupations by risks that does not conform to usual expectations. One of the assumptions of the hedonic technique is that the participants have accurate information regarding the risk characteristics of the job.

To estimate the wage-risk premiums, the extra deaths by occupation variable was matched to the occupations of male heads of households from a random sample of 9,488 representative households contained in the 1967 Survey of Economic Opportunity. The result of this matching was a data set of 907 individuals in the hazardous occupations listed by the Society of Actuaries.

Estimation Results

Weekly wages were estimated as a function of risks and other characteristics of the occupation and the individual. Selected interaction terms were included in several equations to allow for the influence of the individual's characteristics on the risks he faces. Occupation group and industry dummies were also used to account for differences in the type of work. An index measure of socioeconomic status (SES) was used in one equation instead of occupation group dummies. These equations were estimated in linear form and with the natural log of weekly wages as the dependent variable. The variables used are shown in Table 2.4. The estimated equations are shown in Tables 2.5 and 2.6. The only risk coefficient that was significant at the 95 percent confidence level (two tailed test) was in the second linear equation. The risk coefficient in the first linear equation was significant at the 90 percent confidence level and the risk coefficient in the second semi-log equation was significant at just less than 90 percent confidence. These implied

Table 2.3

Thaler and Rosen (1975) Risk Data on Extra Deaths by Occupation

Occupation	Risk [a]	Occupation	Risk [a]
Fishermen	19	Truck drivers	98
Foresters	22	Bartenders	176
Teamsters	114	Cooks	132
Lumbermen	256	Firemen	44
Mine operatives	176		
		Guards, watchmen, and doorkeepers	267
Metal filers, grinders and polishers	41		
Boilermakers	230	Marshals, constables, sheriffs and bailiffs	181
Cranemen and derrickmen	147	Police and detectives	78
Factory painters	81		
Other painters	46	Longshoremen and stevedores	101
Electricians	93	Actors	73
Railroad brakemen	88	Railroad conductors	203
Structural iron workers	204	Ships' officers	156
Locomotive firemen	186	Hucksters and peddlers	76
Power plant operatives	6	Linemen and servicemen	2
Sailors and deckhands	163	Road machine operators	103
Sawyers	133	Elevator operators	188
Switchmen	152	Laundry operatives	126
Taxicab drivers	182	Waiters	134

SOURCE: Society of Actuaries.

[a] Units of measure are extra deaths per 100,000 policy years. To convert to the probability of an extra death per year on each job multiply by 0.00001.

Table 2.4

Variables Used in Thaler and Rosen (1975)

Variable	Mean	Standard Deviation
Dummy variables[a]		
Urban	.69	.46
Northeast	.28	.45
South	.29	.45
West	.17	.38
Family size exceeds 2	.76	.42
Manufacturing industry	.24	.42
Service industry	.58	.49
Worker is white	.90	.30
Worker is employed full time	.98	.10
Worker belongs to union	.45	.49
Worker is married	.92	.26
Occupation is operative	.27	.44
Occupation is service	.45	.49
Occupation is laborer	.22	.42
Continuous variables		
Age (years)	41.8	11.3
Education (years)	10.11	2.73
Weeks worked in 1966	49.4	5.4
Hours worked last week	44.9	11.6
Risk (probability × 10^5)	109.8	67.6
Weekly wage (week prior to survey)	$132.65	50.80

[a] Mean is proportion in sample with designated characteristic. The number of observations is 907.

Table 2.5

Thaler and Rosen (1975) Regression Estimates - Linear Form

Independent Variable	Equation 1	Equation 2	Equation 3	Equation 4
Risk	.0352 (.0210)	.0520 (.0219)	.100 (.108)	.0410 (.102)
Risk × age	–	–	−.0019 (.0018)	−.0030 (.0019)
Risk × married	–	–	.0791 (.0380)	.0701 (.0412)
Risk × union	–	–	.0808 (.040)	.0869 (.042)
Risk × white	–	–	−.118 (.072)	–
Urban	13.80 (4.2)	15.71 (2.95)	17.0 (3.0)	17.0 (3.2)
Northeast	−3.71 (3.65)	−4.29 (3.67)	−4.27 (3.63)	−4.92 (3.83)
South	−8.86 (3.70)	−8.90 (3.74)	−10.5 (3.72)	−8.18 (3.97)
West	9.13 (4.13)	10.30 (4.18)	9.57 (4.12)	9.50 (4.37)
Age	3.89 (0.80)	3.81 (0.83)	3.83 (0.82)	3.78 (0.87)
$(\text{Age})^2$	−.0479 (.0092)	−.0468 (.0097)	−.0442 (.010)	−.0415 (.011)
Education	3.40 (0.55)	3.27 (2.40)	4.13 (2.39)	4.81 (2.80)
$(\text{Education})^2$	–	−.021 (.128)	−.0237 (.128)	−.042 (.148)
Manufacturing industry	–	–	−13.0 (4.3)	−14.7 (4.62)
Service industry	–	–	−9.45 (3.95)	−10.9 (4.24)
White	22.92 (4.53)	22.93 (4.50)	37.7 (9.6)	–
Family size > 2	–	–	.400 (3.57)	2.10 (3.89)
Union	25.5 (3.25)	27.16 (3.23)	15.9 (5.4)	15.39 (5.72)
Full-time	−1.63 (12.9)	−.86 (12.6)	−1.16 (12.6)	.45 (15.0)
Hours worked	1.50 (.12)	1.41 (.12)	1.47 (.123)	1.44 (.129)
Occupation 1: operative	−18.7 (9.2)	–	−13.9 (3.24)	−13.5 (3.51)
Occupation 2: service worker	−24.6 (9.5)	–	−18.1 (4.66)	−19.9 (5.05)
Occupation 3: laborer	−25.0 (13.4)	–	–	–
SES 1	–	4.68 (5.17)	–	–
SES 2	–	−17.17 (3.34)	–	–
SES 3	–	−20.69 (5.53)	–	–
R^2	.41	.41	.42	.39
Number of observations	907	907	907	813
Sample	All	All	All	White only

NOTE: The dependent variable is the weekly wage rate. The SES index has been converted to dummy variables. Standard errors are in parentheses.

Table 2.6

Thaler and Rosen (1975) Regression Estimates - Semilog Linear Form

Independent Variable	Equation 1	Equation 2	Equation 3	Equation 4
Risk	.000206 (.000167)	.000286 (.000174)	.000943 (.000856)	.000108 (.000782)
Age × risk	-	-	−.000022 (.000014)	−.000032 (.000015)
Married × risk	-	-	.000969 (.000301)	.000907 (.000316)
Union × risk	-	-	.000823 (.000315)	.000895 (.000320)
Race × risk	-	-	−.001312 (.000572)	-
Urban	.114 (.033)	.132 (.024)	.144 (.023)	.135 (.024)
Northeast	−.00357 (.00289)	−.00573 (.0291)	−.00904 (.0288)	−.0131 (.0293)
South	−.0632 (.0293)	−.0568 (.0298)	−.0729 (.0295)	−.0459 (.0304)
West	.0857 (.0327)	.0974 (.0332)	.0933 (.0327)	.0855 (.0334)
Age	.0381 (.0063)	.0385 (.0065)	.0390 (.0065)	.0380 (.0067)
$(\text{Age})^2$	−.000469 (.000073)	−.000475 (.000077)	−.000450 (.000078)	−.000419 (.000081)
Manufacturing industry	-	-	−.0790 (.0340)	−.0888 (.0353)
Service industry	-	-	−.0758 (.0314)	−.0922 (.0324)
Education	.0332 (.00436)	.0531 (.0190)	.0623 (.0189)	.0613 (.0215)
$(\text{Education})^2$	-	−.00129 (.00101)	−.00147 (.00102)	−.00133 (.00113)
White	.228 (.036)	.228 (.036)	.389 (.076)	-
Family size > 2	-	−.00204 (.0274)	−.0194 (.0283)	−.00220 (.0297)
Union	.203 (.026)	.214 (.025)	.108 (.043)	.0997 (.0437)
Full-time	.275 (.103)	.303 (.101)	.284 (.100)	.340 (.115)
Hours worked	.0113 (.00096)	.0105 (.00095)	.0109 (.00098)	.0101 (.00099)
Occupation 1: operative	−.0885 (.0728)	-	−.105 (.026)	−.101 (.027)
Occupation 2: service worker	−.126 (.075)	-	−.110 (.037)	−.124 (.039)
Occupation 3: laborer	−.218 (.106)	-	-	-
SES 1	-	.0152 (.0411)	-	-
SES 2	-	−.128 (.026)	-	-
SES 3	-	−.194 (.042)	-	-
R^2	.47	.46	.48	.43
Number of observations	907	907	907	813

NOTE: The dependent variable is the log of the weekly wage rate. The SES index has been converted to dummy variables. Standard errors are in parentheses.

Table 2.7

Estimated Values for a Statistical Life
(1967 dollars)

	Linear Form (Table2.5)	Semilog (Table 2.6)
Equation 1	176,000	136,000
Equation 2	260,000	189,000
Equation 3	117,500	69,300
Equation 4	96,000	5,000

NOTE: All of the coefficients, significant and not significant., were used in these calculations. In the linear equations, the value per life is the risk coefficient plus the interaction coefficients times the mean of the characteristics x 10^5 x 50 (i.e., in Equation 3, this is [.100 + (-.0019 x mean age) + (.079 x mean married) + (.0808 x mean union) + (-.118 x mean white)] x 10^5 x 50. In the semi-log equations, this sum is also multiplied by the mean wage.

average values of life of $260,000, $176,000 and $189,000 respectively.* When the interaction terms were added, two of them (risk x married and risk x union) were significant in most equations, and the risk coefficient itself became insignificant. This adds support to the criticism that the risk measure used is not an accurate measure of risks on the job, but reflects influences of the characteristics of the individuals who choose those jobs. These estimated equations with interaction variables imply values of life ranging from $5,000 to $117,500 when calculated at the sample means.** These values of life estimates are shown in Table 2.7.

Comments

The empirical results of Thaler and Rosen are probably the most cited estimates of the value of a statistical life. These cited estimates have almost always come from Equations 1 and 2 in Table 2.5. Yet, Thaler and Rosen state that the results in Table 2.6 are at least as good as Table 2.5 and the data simply do not provide enough resolution to make a choice. Given this, Table 2.7 presents values of a statistical life from all eight of the Thaler and Rosen specifications.

The questionable applicability of the risk data used in this study lends some doubt to the soundness of the results. If the actuarial data reflect risks beyond those encountered on the job, these risks would not be expected to influence wages. This could account for the low level of significance of the risk coefficients and the instability in the estimates when interaction variables were included.

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* In the linear equations, the value per life is given by the coefficient times 10^5 times 50 work weeks per year. In the semilog equations, this same product must be multiplied by the mean wage.

** All of the coefficients, significant and not significant, were used in these calculations. In the linear equations, the value per life is the risk coefficient plus the interaction coefficients times the mean of the characteristics x 10^5 x 50 (ie., in Equation 3, this is [.100 + (-.0019 x mean age) + (.079 x mean married) + (.0808 x mean union) + (-.118 x mean white] x 10^5 x 50. In the semilog equations, this sum is also multiplied by the mean wage.

2.3.3 W. Kip Viscusi (1978a and 1978b)

Viscusi (1978a and 1978b) considers nonfatal as well as fatal occupational injuries in more detail than previous studies. The data on risks come from the same BLS source that was used by R. Smith (1974). Viscusi augments this with descriptive data on specific job characteristics. This data set also contains a dummy variable that shows whether or not the worker perceived his particular job to be dangerous. These variables help to address one of the criticisms leveled at R. Smith (1974) for his use of BLS data. BLS data only provide a measure of average risks by industry, but job risks in each industry will vary substantially across occupations. Knowing the average risk of injury for the industry in which the worker is employed as well as whether the worker perceives himself to be working in a dangerous occupation within that industry, provides more information to be used in the estimation of wage premiums.

Data Used

Rather than using the Survey of Economic Opportunity (used by R. Smith (1974, 1976) and Thaler and Rosen (1976)), Viscusi used the 1969-70 Survey of Working Conditions compiled by the University of Michigan for data on individual earnings and other job and individual characteristics. These data provide more descriptive information about job characteristics. This data set contains a number of variables that pertain to each worker's particular job including:

SIZE = number of employees at the enterprise
UNION = member of union
SUPER = whether the worker is a supervisor
FAST = whether the worker is required to work fast
NODEC = whether the worker is not allowed to make decisions
MISTAKE = whether the job requires that the worker not make mistakes
SECURITY = presence of job security
OVERT = overtime work
TRAIN = training program available

This should improve the ability to isolate variations in wages attributable to differences in risks by better describing job characteristics and reducing omitted variable bias. The sample for this study included 495 full-time blue-collar workers. Risk data included fatal injuries and nonfatal disabling injuries by industry. The average annual probability of a job injury for workers in the sample was .0319--.00012 for fatal and .0318 for nonfatal disabling injuries. The two risk variables used are INJRATE and DANGER. INJRATE is the number of disabling injuries per million hours worked for the workers in each industry. Disabling injuries were defined as those causing some permanent impairment or injuries resulting in the worker being unable to work at his regular job for at least one full day. Fatal injuries made up .4 percent, permanent partial disability made up 2.9 percent and temporary total disabilities made up 96.7 percent of total injuries. Unlike R. Smith (1974), no attempt was made to distinguish actual injury by severity except by separating INJRATE into DEATH (fatal injuries) and NONFATAL (nonfatal injuries). The DANGER variable is a self-assessed dummy variable measuring whether the worker felt his job to be dangerous.

Estimation Results

Annual earnings and the natural log of annual earnings were taken as a function of risk variables, job characteristics and individual characteristics as shown in Table 2.8. In Equations (1) and (3) the perceived job danger dummy variable was used. In Equations (2) and (4) the injury variable was used. In both cases, the risk variable coefficient was positive and statistically significant at the 95 percent confidence level.

The results from equation (1) show that the risk premium paid to workers who work in self-assessed dangerous jobs is $375 (1969 dollars) per year or roughly 5.5 percent of the workers' mean salary. Equation (2) uses the injury rate as the risk variable. The wage premium for an increase of one injury per million hours is $26. Using the median injury rate of 15.93 injuries per million hours, the mean level risk premium paid to workers is $415 per year. These risk measures do not explicitly break out the risk of fatal injuries. Estimates of the value of a statistical life could be made by adopting various assumptions about the allocation of this premium to fatal and nonfatal injuries. Viscusi attempted to separate the effects of fatal and nonfatal injuries in a second paper.

In Viscusi (1978b), the author used the same data set but he incorporated separate measures of fatal and nonfatal injuries in the equations. The fatal injuries variable (DEATH) was calculated by multiplying the total injury rate by the percentage of fatal injuries.

Table 2.8

Regression Results from Viscusi (1978a)

Independent Variables	Coefficients and Standard Errors			
	EARNG		*LOGEARNG*	
	1	2	3	4
AGE	+138.22 (45.50)	+163.74 (44.40)	+.025 (.0072)	+.030 (.0070)
AGE × AGE	−1.63 (0.53)	−1.96 (0.51)	−.28E−3 (.083E−3)	−.34E−3 (.082E−3)
FEMALE	−2585.9 (278.9)	−2809.3 (244.8)	−.507 (.044)	−.534 (.039)
BLACK	−382.38 (276.19)	−429.00 (269.54)	−.063 (.044)	−.067 (.043)
EDUC	+128.84 (33.34)	+136.14 (32.76)	+.024 (.0053)	+.025 (.0052)
HEALTH	−194.91 (93.88)	−168.92 (93.14)	−.019 (.015)	−.017 (.015)
SINGLE	−1088.6 (343.9)	−981.16 (328.75)	−.231 (.054)	−.210 (.052)
SIZE	+0.233 (0.119)	+0.305 (0.104)	+.25E−4 (.19E−4)	+.38E−4 (.16E−4)
UNION	+543.07 (206.88)	+645.05 (196.53)	+.109 (.033)	+.113 (.031)
TENURE	+12.40 (11.28)	+6.25 (10.87)	−.13E−3 (1.78E−3)	−.0015 (.0017)
DANGER	+374.82 (177.67)	— —	+.055 (.028)	— —
INJRATE	— —	+26.37 (10.14)	— —	+.0040 (.0016)
SUPER	+372.24 (193.89)	+414.69 (191.43)	+.032 (.031)	+.043 (.030)
FAST	+519.54 (189.64)	+460.82 (184.22)	+.072 (.030)	+.063 (.029)
NODEC	−121.78 (83.85)	−146.67 (82.38)	−.016 (.013)	−.021 (.013)
MISTK	−127.91 (85.31)	−140.29 (82.79)	−.023 (.013)	−.027 (.013)
SECURITY	+521.27 (177.90)	+496.28 (172.06)	+.093 (.028)	+.097 (.027)
OVERT	+170.12 (67.41)	+191.76 (64.66)	+.032 (.011)	+.037 (.010)
TRAIN	+362.08 (201.14)	+519.59 (193.27)	+.059 (.032)	+.099 (.031)
Other Variables	LIST1	LIST2	LIST1	LIST2
R^2	.641	.611	.698	.669
S.E.E.	1813.5	1836.6	.286	.291

Note: Each equation also includes the variable lists *LOCATE* and *JOB*. Equations (1) and (3) also include industry dummy variable list *INDUSTRY*, which is omitted from the equations including *INJRATE* since this job risk index was constructed using information regarding the worker's industry.

Similarly, the variable NONFATAL was found by multiplying the total injury rate for each industry by the number of injuries that were nonfatal. The information on whether the worker assessed his job to be dangerous was used to construct three additional risk variables—INJRATE1, DEATH1, and NONFATAL1. These variables were constructed by multiplying the variables INJRATE, DEATH and NONFATAL by the 0 or 1 dummy variable DANGER. Thus, the risk level in the equation was zero if the worker did not perceive his job to be hazardous. Where the worker did perceive his job to be hazardous, the industry average risk variables were used.

Tables 2.9 and 2.10 give the results for the risk variables in the specifications where fatal and nonfatal injuries were separate or were multiplied by the perceived danger variable. The implied average values of life range from $.6 million to $1.8 million, with the majority falling between $1 million and $1.5 million. If multicollinearity is not a problem, the estimates from the equations with both fatal and nonfatal injuries included are preferable. The nonfatal coefficient implies an average valuation per injury of $5,500 to $9,500.

One issue that is not addressed in any of Viscusi's analyses is that the risk variables, specifically the self assessed danger variable, may not be independent of other job characteristics included in his specification. For example, it is possible that individuals who classify themselves as supervisors will not be subject to as many occupational risks in an otherwise hazardous industry and may not warrant wage premiums when compared to other industries. Some exploration of risk and job characteristic interactions might have been fruitful.

2.3.4 Alan E. Dillingham (1979)

This Ph.D. dissertation examined the market for occupational safety. The points of view of both producers and consumers (employers and employees) were considered, although no attempt was made to estimate simultaneously the supply and demand for occupational safety. The theoretic discussion in Dillingham (1979) might provide a starting point for future attempts to specify the wage-risk tradeoff from the employer's side. A hedonic function for wages was specified in an attempt to quantify wage-risk premiums.

Table 2.9

Summary of Death Risk Regression Results from Viscusi (1978b)
(1969 Dollars)

		LOGEARNINGS results		*EARNINGS results*	
Death risk variable	*Other job risk variables included in equation*	*Death risk coefficient (std. error)*	*Implied value of life*	*Death risk coefficient (std. error)*	*Implied value of life*
1. Industry death risk (DEATH)	. . .	0.00205 (0.00075)	1,595,000	35.39 (10.73)	1,769,500
2. Industry death risk (DEATH)	Nonfatal injury rate (NONFATAL)	0.00153 (0.00088)	1,185,000	29.20 (12.69)	1,460,000
3. Industry death risk (DEATH)	Self-assessed dangers (DANGER)	0.00183 (0.00075)	1,420,000	32.13 (10.81)	1,606,500
4. Industry death risk conditional on self-perceived hazard (DEATH1)	. . .	0.00189 (0.00072)	1,490,000	34.08 (10.38)	1,704,000
5. Industry death risk conditional on self-perceived hazard (DEATH1)	Nonfatal injury rate conditional on self-perceived hazard (NONFATAL1)	0.00076 (0.00093)	600,000	18.27 (13.33)	913,500
6. Industry death risk conditional upon self-perceived hazard (DEATH1)	Self-assessed dangers (DANGER)	0.00141 (0.00079)	1,080,000	27.93 (11.40)	1,396,500

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[a] Complete regression results are not reported here, since they are similar to those reported in Viscusi (forthcoming, b); the only difference is the inclusion of death risk and nonfatal injury risk variables in this analysis. Two of the equations in the aforementioned paper correspond to those in line 1 in Table 3.

Table 2.10

Summary of Injury Risk Regression Results from Viscusi (1978b)
(1969 Dollars)

		LOGEARNINGS results		*EARNINGS results*	
Injury risk variable	*Death risk variable included in equation*	*Injury risk coefficient (std. error)*	*Implied value of injury*	*Injury risk coefficient (std. error)*	*Implied value of injury*
1. Unspecified job injury (INJRATE)	. . .	0.0040 (0.0016)	13,550	26.37 (10.14)	13,185
2. Unspecified job injury conditional on self-perceived hazard (INJRATE1)	. . .	0.0040 (0.0013)	13,550	27.72 (7.83)	13,860
3. Industry nonfatal injury rate (NONFATAL)	Industry death rate (DEATH)	0.932E-5 (0.837E-5)	5,500	0.110 (0.121)	5,500
4. Industry nonfatal injury rate, conditional on self-perceived hazard (NONFATAL1)	Industry death rate conditional on self-perceived (DEATH1)	0.136E-4 (0.704E-5)	9,500	0.191 (0.101)	9,500

Data Used

Dillingham used injury data from the New York Workmen's Compensation Board for injuries occurring in 1970 and employment data from the 1970 Census. These were matched by industry and occupations excluding a few categories of workers, such as federal employees not covered by worker's compensation. Each individual was assigned a risk according to his or her occupation, industry of employment, age, and sex. The author points out that the disaggregate level of the data led to a limited number of observations in many cells, introducing the possibility of measurement error. Injury rates by sex and age are given in Table 2.11. These are injuries per million employee hours. Assuming 200 work hours per year per employee, these data translate into annual injury rates per 500 employees.

For estimating the wage-risk equation, two smaller samples were used--full time employed males and full time males in blue collar occupations in manufacturing and construction. The mean values of the variables included in the model are shown in Table 2.12.

Estimation Model

Several specifications of a hedonic wage function were estimated for both samples. The dependent variable was the natural log of annual earnings. Death rates and various combinations of nonfatal injury rate measures were used in each equation. Permanent partial disabilities were divided into parts of the body affected: (1) trunk, (2) upper extremities, (3) lower extremities, and (4) not categorized. Interaction variables with fatal injuries multiplied by age, education, unmarried and nonwhite were also included to account for different productivity effects of injuries or to capture correlations between injury rates and worker characteristics that have not been accounted for.

Estimation Results

When all the injury variables were included, they were insignifcant individually and as a group in the estimated equation for the first sample (all full-time employed males). When only the fatal injury rate was included in the equation, it was found to be significant with a coefficient of .2325. Ignoring the interaction coefficients which were all

Table 2.11

Injury Rates per Million Employee Hours by Age and Sex, Estimates for New York, 1970, from Dillingham (1979)

	Injury Rates[a]						
Age/Sex Group	Death (1)	Permanent Total (2)	Permanent Partial (3)	Temporary (4)	Temporary Severity (5)	Aggregate (6)	Lost Time Temporary[b] (7)
a) All Age/Sex Groups	.054	.013	4.148	5.712	203.913	9.927	36.174
Sex Age							
b) Males—all ages	.077	.018	5.216	6.844	243.670	12.156	36.099
c) less than 25	.066	.015	8.349	14.066	399.644	22.496	28.861
d) 25-44	.048	.007	4.679	6.265	218.155	11.017	35.210
e) 45 and over	.111	.032	5.081	5.800	235.599	11.024	41.153
f) Females—all ages	.006	.001	2.486	3.355	121.212	5.288	36.477
g) less than 25	.007	...	1.244	3.269	97.699	4.519	30.106
h) 25-44	.003	...	1.567	3.340	126.294	4.910	38.220
i) 45 and over	.008	.002	2.496	3.402	126.319	5.908	37.639

[a] Injury Rate Definitions:

$$\text{frequency rate} = \frac{(\text{number of injuries}) \times 10^5}{\text{Employee-Hours Exposure}} \qquad \text{severity rate} = \frac{(\text{lost time from injuries}) \times 10^6}{\text{Employee-Hours Exposure}}$$

$$\text{average Days lost} = \frac{\text{Total Days Lost}}{\text{Number of Injuries}}$$

[b] This column refers to average days lost per temporary injury.

Table 2.12

Mean Values of Variables by Sample and Race for Males, New York, 1970, from Dillingham (1979)

Variables	All Occupations/Industries			"Blue Collar", Manufacturing and Construction		
		Whites Only	Nonwhites Only		Whites Only	Nonwhites Only
Fatal Injury Rate (D)	0.068	0.066	0.079	0.086	0.088	0.070
Permanent Total Injury Rate (PT)	0.020	0.020	0.015	0.053	0.055	0.037
Permanent Partial Injury Rate (PP)	5.498	5.365	6.431	10.660	10.511	11.824
Permanent Partial Location 1 Rate (PP Loc 1)	0.137	0.130	0.185	0.209	0.204	0.246
Permanent Partial Location 2	2.884	2.821	3.324	5.880	5.812	6.407
Permanent Partial Location 3	1.368	1.337	1.588	2.320	2.293	2.533
Permanent Partial Location 4	1.109	1.077	1.334	2.251	2.201	2.638
Temporary Injury Rate (Temp)	7.393	7.066	9.684	11.515	11.228	13.756
Educational Attainment	11.110	11.240	10.210	9.950	10.030	9.320
Experience (Age-Education-6)	25.410	25.650	23.680	26.870	27.210	24.250
Annual Earnings	$9,566	$9,969	$6,743	$8,217	$8,405	$6,752
Proportion of Sample who are:						
Nonwhite	0.125			0.114		
Unmarried	0.196	0.190	0.240	0.178	0.170	0.236
Government employees (Govt Emp)	0.153	0.152	0.158			
Professional workers	0.121	0.128	0.066			
Managers	0.093	0.102	0.031			
Sales workers	0.067	0.071	0.041			
Craftsmen	0.227	0.236	0.164	0.459	0.476	0.328
Operatives	0.200	0.186	0.295			
Laborers	0.060	0.057	0.081	0.088	0.083	0.132
Farmers	0.002	0.001	0.003			
Service workers	0.139	0.127	0.225			
Household workers	0.001	0.001	0.003			
in Agriculture	0.004	0.004	0.005			
in Construction	0.070	0.073	0.049			
in Durable manufacturing	0.238	0.248	0.161	0.545	0.547	0.531
in Nondurable manufacturing	0.116	0.117	0.109	0.242	0.235	0.295
in Utilities, Transportation & Communication	0.127	0.123	0.160			
in Service Industries	0.229	0.219	0.298			
in Public Administration	0.057	0.060	0.037			

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insignificant, this implies a value per life of about $1.1 million (1970 dollars). If the interaction coefficients are included in the calculation, as could be justified if it were argued that multicollinearity was the cause of the low t-statistics, this figure drops to about $20,000.

With the narrower blue collar sample (about half the size of the first sample), the coefficients on the fatal injuries variable were significant in all but one specification. These results are presented in Table 2.13. The coefficients for the nonfatal injury variables were not significant except for one of the partial permanent injury variables that had a negative coefficient. The author points out that workers' compensation may eliminate the need for a compensating wage premium (or make it so small as to be insignificant) for nonfatal injuries. The coefficient on the fatal injury variable was, however, greater when nonfatal injuries were excluded indicating that it might be picking up some nonfatal injury effects.

The values per life implied by the second sample range from $140,000 to $450,000. In discussing the different results for the two samples, the author points out that the average injury rates for white collar workers are lower than national average injury rates at home (6.95 per 1,000,000 hours in 1970 according to the National Safety Council). For comparison, the average injury rates by occupation in this sample are given in Table 2.14. A risk premium may not be associated with all jobs, if the jobs are not perceived as any riskier than normal day to day activities. Table 2.15 presents the estimates for value of life from each specification considered by Dillingham.

2.3.5 Craig A. Olson (1981)

In an attempt to quantify wage differentials attributable to differences in risks across jobs, Olson used a more flexible functional form and provided a more detailed analysis of the effects of injury severity and of union membership upon risk premiums.

Data Used

The May 1973 Current Population Survey provided the information on individual employees. The sample was limited to those who worked 35 hours a week or more, were in the private sector, and had no missing information for the variables used. Nonfatal accident variables came from the U.S. Department of Labor, Occupational Safety and Health Statistics: Concepts and Methods, Report 518, 1978. Fatal accidents were calculated from unpublished Bureau of Labor Statistics numbers on 1973 fatalities divided

Table 2.13

Estimated Earnings Functions for Male Blue Collar Workers in Manufacturing and Construction from Dillingham (1979)

(Dependent Variable: natural log of annual earnings)

			Equations	#4	#5
Independent Variable	#1	#2	#3	Whites Only	Nonwhites Only
Constant	7.585	7.618	7.575	7.612	7.299
Death	0.0409* (0.0215)	0.0343 (0.0219)	0.3182* (0.1869)	0.0401* (0.0229)	0.1092* (0.0661)
PT	0.0154 (0.0230)	0.0091 (0.0232)		0.0123 (0.0243)	0.0758 (0.0748)
PP	-0.0004 (0.0014)			0.0000 (0.0016)	-0.0044 (0.0036)
PP Loc 1		0.0144 (0.0189)			
PP Loc 2		-0.0040* (0.0022)			
PP Loc 3		0.0040 (0.0048)			
PP Loc 4		0.0063 (0.0043)			
Temp	0.0004 (0.0010)	-0.0002 (0.0011)		0.0000 (0.0011)	0.0031 (0.0024)
ED	0.0681** (0.0231)	0.0649** (0.0213)	0.0695** (0.0213)	0.0629** (0.0233)	0.1578** (0.0564)
ED^2	0.0009 (0.0009)	0.0010 (0.0009)	0.0009 (0.0009)	0.0013 (0.0009)	-0.0048* (0.0025)
EX	0.0470** (0.0051)	0.0456** (0.0051)	0.0467** (0.0050)	0.0461** (0.0055)	0.0492** (0.0138)
EX^2	-0.0005** (0.0001)	-0.0005** (0.0001)	-0.0005** (0.0001)	-0.0005** (0.0001)	-0.0004** (0.0002)
EDEX	-0.0016 (0.0003)	-0.0015** (0.0003)	-0.0016** (0.0003)	-0.0016** (0.0003)	-0.0019** (0.0008)

Table 2.13 (cont.)

Independent Variable	Equations				
	#1	#2	#3	#4 Whites Only	#5 Nonwhites Only
Nonwhite	-0.1171** (0.0312)	-0.1199** (0.0312)	-0.1175** (0.0317)		
Unmarried	-0.1882** (0.0253)	-0.1852** (0.0253)	-0.1889** (0.0257)	-0.1988** (0.0281)	-0.1354** (0.0522)
Mobility	-0.0135 (0.0263)	-0.0129 (0.0263)	-0.0151 (0.0263)	-0.0183 (0.0293)	0.0127 (0.0523)
Urban	0.0128 (0.0273)	0.0122 (0.0273)	0.0133 (0.0273)	0.0152 (0.0283)	0.0214 (0.1421)
Metro	0.1549** (0.0279)	0.1534** (0.0279)	0.1560** (0.0279)	0.1665** (0.0290)	-0.2587** (0.1301)
Central City	-0.1422** (0.0233)	-0.1408** (0.0233)	-0.1428** (0.0233)	-0.1555* (0.0248)	0.0701 (0.0704)
Craftsmen	0.1295** (0.0212)	0.1259** (0.0213)	0.1282** (0.0209)	0.1306** (0.0229)	0.1131** (0.0523)
Laborer	0.0072 (0.0388)	-0.0093 (0.0399)	0.0074 (0.0368)	0.0394 (0.0432)	-0.1654** (0.0767)
Durable Manufacturing	0.0090 (0.0261)	0.0200 (0.0267)	0.0093 (0.0260)	0.0034 (0.0281)	0.0613 (0.0663)
Nondurable Manufacturing	-0.0474 (0.0300)	-0.0313 (0.0309)	-0.0462 (0.0298)	-0.0512 (0.0326)	0.0050 (0.0708)
Ed x Death			-0.0117 (0.0089)		
Nonwhite x Death			0.0271 (0.0773)		
Age x Death			-0.0034 (0.0028)		
Unmarried x Death			0.0025 (0.0491)		
R^2	0.137	0.138	0.137	0.128	0.174
Standard Error	0.571	0.570	0.571	0.584	0.442
Degrees of Freedom	3709	3706	3708	3286	405
F Statistic	30.956	27.028	29.504	26.909	4.749

Note: Standard errors are in parentheses. An * indicates significance at the 10 percent level; an ** indicates significance at the 5 percent level (two-tailed tests). The reference occupation/industry group is operatives in construction. The relevant F statistic is no larger than $F_{0.99(18,\infty)} \approx 2.00$.

Table 2.14

Average Injury Rates by Occupation in Dillingham Sample*

White Collar:	
Professional, technical	.94
Manager, administrator	2.15
Sales workers	2.17
Clerical workers	5.41
Blue Collar:	
Craftsmen	12.92
Operatives	21.72
Laborers	49.92
Service workers	11.27

* These are injuries per 1,000,000 hours.

Table 2.15

Estimates of the Value of a Statistical Life from Dillingham (1979)
(1970 Dollars)

	Sample I All Occupations and All Industries		Sample II Blue Collar Workers in Manufacturing	
Equations	Value	Mean Risk[a]	Value	Mean Risk[a]
1	N.S.	-	\$168,037	1.72
2	N.S.	-	\$140,921	1.72
3[b]	\$23,030	1.36	\$174,549	1.72
4	N.S.	-	\$164,750	1.76
5	\$458,524	1.58	\$448,648	1.4

[a] Deaths per 10,000 workers per year.

[b] Interaction variable coefficients were included in the calculation

N.S. = coefficients were not statistically significant by full time equivalent employment reported in Occupational Injuries and Illnesses 1973 or Employment and Earnings. Variables were constructed for fatal accidents, lost work day accidents, and the average number of days lost for the industry in which the individual was employed.

Estimation Model

The dependent variables used were natural log of weekly earnings and natural log of hourly earnings. The fatal accident variable was entered linearly and squared to allow for the possibility of a concave wage-risk function. This could be expected to occur if less risk averse individuals accept riskier jobs and have lower marginal valuations on risks. The tradeoff between wages and risks could then be expected to increase at a decreasing rate. The functional forms used in previous studies have constrained wages to be either a linear function of risks or an increasing function of risks. Olson's functional form allows the relationship to go either way.

Both the frequency of lost work day accidents and the average number of days lost were entered linearly, the latter to represent accident severity. The author was interested in testing whether income lost is an adequate measure of compensation or whether the pain and suffering of longer recuperations requires more compensation than an equal number of work days lost due to less severe accidents. This test was probably confounded by the effects of workers' compensation that may diminish or eliminate any income lost due to accidents on the job. Olson did not take this problem into account.

Estimation Results

The variables used and estimation results obtained are presented in Table 2.16. The coefficient on fatal injuries was positive and significant. The coefficient on the fatal injuries squared variable was negative and significant. This provides support for the hypothesis that wage premiums for marginal changes in risk decline as the total risk levels of jobs increase, because individuals who are less risk averse take jobs with higher risks. At the means of the variables, these coefficients imply value of life estimates of \$3.2 to \$3.4 million (1973 dollars). Over the range of the risks in the sample (approximately $.015 \times 10^{-3}$ to $.30 \times 10^{-3}$ annual probabilities of fatal accidents per worker) the value of life estimates range from about \$3.7 million to \$2.2 million. The nonlinear term DTH^2

Table 2.16

Regression Results and Variables Used in Olson (1981)
(Standard errors in parentheses)

Independent Variables	Dependent Variable		Mean (SD)
	ln(Hourly Earnings)	ln(Weekly Earnings)	
Constant	−.0704	3.5944	—
	(.0748)	(.0744)	
NEAST	—	—	—
NCENT	−.0244	.0089	.2962
	(.0128)	(.0127)	(.4566)
SOUTH	−.0915	−.0681	.3024
	(.0129)	(.0129)	(.4593)
WEST	.0068	.0304	.1774
	(.0145)	(.0144)	(.3820)
URBAN	.1728	.1578	.7432
	(.0107)	(.0106)	(.4369)
AGE	.0419	.0448	36.58
	(.0025)	(.0025)	(12.6)
AGE^2	−.0005	−.0005	1497
	(.00003)	(.00003)	(.1006)
BLACK	−.1166	−.1338	.0671
	(.0187)	(.0186)	(.2502)
NONWHT	−.0731	−.0778	.0087
	(.0492)	(.0489)	(.0928)
SEX	−.3246	−.3892	.3517
	(.0315)	(.0313)	(.4776)
EDUC	.0479	.0498	12.61
	(.0028)	(.0028)	(1.938)
APART	.0818	.0747	.7360
	(.0262)	(.0260)	(.441)
SEX × *APART*	−.0500	−.0611	.2097
	(.0328)	(.0326)	(.4072)
NEVMAR	−.1383	−.1745	.1612
	(.0303)	(.0301)	(.368)
SEX × *NEVMAR*	.1823	.0281	.0713
	(.0382)	(.0379)	(.2573)
PROF	—	—	—
MGMT	−.0460	.0348	.1268
	(.0193)	(.0192)	(.3328)
SALES	−.2441	−.2156	.0763
	(.0220)	(.0219)	(.2654)
CLERKS	−.1769	−.1831	.2024
	(.0189)	(.0189)	(.4018)
CRAFTS	−.1371	−.1348	.1819
	(.0205)	(.0203)	(.3858)

Table 2.16, cont.

Independent Variables	Dependent Variable ln(Hourly Earnings)	 ln(Weekly Earnings)	Mean (SD)
OPER	−.2740	−.2548	.1245
	(.0220)	(.0219)	(.3302)
TRANOP	−.3360	−.2712	.0536
	(.0274)	(.0272)	(.2252)
LABOR	−.3458	−.3475	.0437
	(.0287)	(.0285)	(.2045)
SERVICE	−.4115	−.3908	.0813
	(.0233)	(.0231)	(.2733)
UNION	.2027	.1559	.2591
	(.0121)	(.0120)	(.4382)
DTH	.4245	.4075	.09508
	(.0719)	(.0715)	(.1444)
DTH^2	−.2904	−.2569	.0299
	(.0688)	(.0684)	(.1224)
P	.7247	.9083	.0346
	(.2866)	(.2869)	(.0222)
D	.0030	.0042	14.985
	(.0014)	(.0014)	(3.641)
$\bar{R}^2$	.5006	.5406	

Independent Variables	*Definitions*
Region	Region is composed of three dummy variables, *NCENT*, *SOUTH*, and *WEST*, indicating the region in which the individual lives. The excluded category is *NEAST*. The states included in each region are defined by the Census.
URBAN	1 if living in an SMSA, 0 otherwise.
AGE	Age of the individual.
AGE^2	Age squared.
BLACK	1 if the individual is black, 0 otherwise.
NONWHT	1 if the individual is neither white nor black, 0 otherwise.
SEX	1 if the individual is female, 0 otherwise.
EDUC	Years of school completed.
APART	1 if the individual is married.
NEVMAR	1 if the individual was never married, 0 otherwise.
Occupation	The occupational categories, *MGMT*, *SALES*, *CLERKS*, *CRAFTS*, *OPER*, *TRANOP*, *LABOR*, and *SERVICE* are based of the 1970 *Census of Population* occupational codes. *PROF* is the omitted category.
UNION	1 if the individual is a union member, 0 otherwise.
DTH	Probability of experiencing a fatal occupational accident in 1973.
DTH^2	*DTH* squared.
P	Probability of experiencing a lost-workday accident in 1973.
D	Average lost workdays per lost-workday injury in 1973.

causes the estimated value of life based on marginal willingness to pay to decline as risks increase. This is because the marginal wage premium for reductions in risk declines as risks increase even though the total wage premium may be increasing.

The discrepancy with R. Smith's results (a study which used virtually the same data set) was largely reconciled when the squared item was dropped. Value of life estimates of about $1.8 million were then found. Such dramatic differences due to changes in the functional form indicate that this should be more carefully explored in future studies.

Olson's estimates of wage premiums were approximately an order of magnitude higher than those found by Thaler and Rosen. Two reasons for the differences between these estimates were offered by Olson. The first was that the occupations examined by Thaler and Rosen were the more risky occupations which are likely to attract less risk averse individuals. As a result, the risk premiums required by these workers could be substantially less than those required by the average population. The second reason offered for the difference in estimates from the two studies stems from the nature of the occupational risk used in Thaler and Rosen. The Thaler and Rosen mortality risks include both occupational risks and all other risks. To obtain only occupational risks, Thaler and Rosen subtract age adjusted average mortality rates. If it is true that workers on risky jobs are less risk averse than the population in general, then it may be the case that they are less risk averse in other life activities. This would result in Thaler and Rosen's adjusted measure of occupational risk being biased on the high side. Subtracting age adjusted average mortality rates for the entire population will not fully account for the nonwork risks faced by this less risk averse group. This measurement error will then lead to estimated coefficients that are biased downward. Thus, the Thaler and Rosen study may underestimate the actual wage-risk premium.

The nonfatal accident variables used by Olson had positive coefficients that were significant. When the product P (probability of nonfatal accident) x D (average number of days work missed) was held constant, wage differentials increased as D increased (and P decreased). This was interpreted as evidence that compensation for pain and suffering was an important component of this premium. The coefficients indicate a premium per nonfatal accident of about $6700 to $7900, with $28 to $37 for each additional day lost from work at the mean income levels of the sample.

The only statistically significant interaction terms were with risks and union status. These results are presented in Table 2.17. The union-risk interaction terms indicate that

Table 2.17

Union and Nonunion Accident Wage Differentials from Olson (1981)

	Union and Accident Interaction Terms		Accident Coefficients for Union Members		Accident Coefficients for Nonunion Employees	
	ln(Weekly Earnings)	ln(Hourly Earnings)	ln(Weekly Earnings)	ln(Hourly Earnings)	ln(Weekly Earnings)	ln(Hourly Earnings)
	(a)	(b)	(c)		(d)	
UNION	.234	.195				
	(.054)	(.054)				
DTH	.172	.176	1.094	1.139	.167	.177
	(.086)	(.086)	(.126)	(.122)	(.090)	(.019)
DTH^2	−.069	−.074	−1.044	−1.194	−.071	−.084
	(.074)	(.075)	(.168)	(.163)	(.078)	(.079)
P	.273	−.049	1.483	1.755	.486	.202
	(.341)	(.342)	(.499)	(.436)	(.360)	(.365)
D	.011	.009	−.003	−.002	.011	.009
	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
DTH × *UNION*	.830	.895				
	(.170)	(.171)				
DTH^2 × *UNION*	−.868	−1.038				
	(.215)	(.216)				
P × *UNION*	1.816	2.497				
	(.618)	(.621)				
D × *UNION*	−.014	−.011				
	(.003)	(.003)				

Note: Standard errors are in parentheses.

union members receive higher wage-risk premiums. However, the coefficient for average number of days lost per accident times union membership was negative. To allow for the possibility of differences in other coefficients, the sample was separated into union and nonunion. Here the union coefficient for number of days was again negative. For the nonunion group this coefficient was positive, but the coefficient for probability of nonfatal accidents was insignificant. These differences could result from measurement error in injury variables that is correlated with union membership and, in any case, lend uncertainty to robustness of these coefficients.

The fatal injury coefficients indicate a much higher premium is paid to union workers. The estimated value per life for union workers was about $8 million (1973 dollars), when for nonunion workers it was about $1.5 million. The author offers several possible explanations: (1) unions may force employees to lower isoprofit curves, (2) nonunion workers may be less aware of risks, and (3) unions may be active in promoting safety, causing union members to have fewer accidents, hence causing a systematic error in the measurement of risk.

2.3.6 V. Kerry Smith (1982)

V. K. Smith attempts to consider both the variation across jobs and variations across locations in a hedonic wage model. The literature on wage rate differentials has developed along two lines (see V. K. Smith, 1982, for references). First, a number of wage rate studies have been based on specific job characteristics where job risks have typically been the principal job characteristic used to explain wage rate differentials. A second set of studies has used the assumption that households select residential locations to maximize welfare. The wage rate is one of the equilibrating mechanisms used to explain worker migration among cities. Although both types of models were designed to explain wage rate differentials, there has been no previous attempt to incorporate both site characteristics and job characteristics within a more general wage rate model.

The V. K. Smith study makes a contribution to the literature in several other areas as well. The wage rate was adjusted for differences in the cost of living by location. Smith points out that the use of regional dummy variables to capture factors that vary across regions, such as cost of living differences, assumes that intraregional differences in the cost of living are inconsequential. He argues, however, that in his data set the cost of living varied by as much as 10 percent across the SMSAs in a given region. This was true for most regions as they have been conventionally defined.

Other unique aspects included the use of an index of exposure to carcinogens by industry and a variable designed to measure the knowledge of job hazards by workers in each industry. The index of exposure to carcinogens attempts to account for the carcinogenic potential of organic or inorganic chemicals and the estimated number of exposures. This index of exposure cannot be translated into a probabilistic risk factor but it is a mechanism for controlling for the effect on wages of health risks with a long latency period.

The measure of knowledge (KNOW) used by V. K. Smith was the fraction of workers in an industry covered by collective bargaining agreements with provisions specifically addressing health and safety conditions. The assumption is that an agreement of this type reflects some concern over hazards, and as a result, better information on all risks may be available.

Data Sources

The May 1978 Current Population Survey provided residential location, occupation, industry of employment, weekly earnings, and other socioeconomic characteristics of the individuals. The sample used included all individuals who reported positive weekly earnings. Table 2.18 shows the site specific variables for the 44 SMSAs used in the analysis. Other variables included education (EDU), experience (POTEXP), socioeconomic variables (race, veteran status, union member, head of household, and dual job holder), and occupational qualitative variables for different labor categories (i.e., professional, manager, sales, clerical, craftsman, operative, transport equipment operator, nonfarm labor, and service). The 1975 Bureau of Labor Statistics, Occupational Injuries and Illnesses in the United States by Industry provided the injury frequency data. The index of exposure to carcinogens (CANCER) was obtained from John L.S. Hickey and James J. Kearney, "Engineering Control Research and Development Plan for Carcinogenic Materials," a report to the National Institute for Occupational Safety and Health, September 1977.

Table 2.18

Site Specific Attributes Considered as Potential Determinants of Real Wage Rates (V.K. Smith, 1982)

Variable	Definition	Source
TSP	Total suspended particulates in micrograms per cubic meter, measured as the annual geometric mean at sites with complete data for 1978	Environmental Protection Agency - Tables of Indicator Values for Five pollutants in 102 urbanized areas
CRIME	Serious crime rate per 100,000 inhabitants of the SMSA in 1975	County and City Data Book, 1977
UN78	Average Unemployment rate for 1978 for the SMSA	Employment & Training Report of the President, 1979
HOSP	Number of Hospitals in the SMSA	County and City Data Book, 1977
SPORTS	Number of Professional Sporting Teams in SMSA (includes baseball, basketball, hockey, football, and soccer)	World Almanac, 1980
SYMP	Presence of a Symphony (present = 1; absent = 0)	Hammond Almanac, 1980
THEAT	Presence of Live Theatre (present = 1; absent = 0)	Hammond Almanac, 1980
MUSE	Number of major art museums	Hammond Almanac, 1980
NEWS	Number of major newspapers	World Almanac, 1980
SUN	Mean annual percentage of possible sunshine (i.e., number of hours of sunshine recorded by instrument and the number of hours between sunrise and sunset for each day)	County and City Data Book, 1977
THIGH	High temperature (°F)	County and City Data Book, 1977
TLOW	Low temperature (°F)	County and City Data Book, 1977
WIND	Average annual wind speed (miles per hour)	County and City Data Book, 1977
RAIN	Average annual precipitation	County and City Data Book, 1977

Table 2.19

Sample Means for Selected Variables from V.K. Smith (1982)

Variable	Full Sample	Males	Females
Nominal hourly wage rate	6.18	7.22	4.86
Education	12.8	12.9	12.7
Experience Proxy	17.0	17.3	16.6
Race (proportion white)	0.86	0.88	0.85
Male	0.56	--	--
Household Head	0.57	0.81	0.27
Veteran	0.23	0.40	--
Unemployment rate in 1978	6.1	6.1	6.1
BLS Injury Rate	7.8	8.9	6.4
Union	0.25	0.32	0.17
Total suspended particulates	67.1	67.0	67.2

Estimation Results

Several different specifications of a semilog regression equation were estimated for the whole sample and separately for males and females. The dependent variable was the real hourly wage rate. Nominal wages were adjusted for local cost of living. Multiplicative interaction variables were included in some specifications. Site specific attributes included air pollution, crime rate, unemployment, weather, and number of urban facilities, such as museums and hospitals.

The injury coefficients are reasonably consistent across specifications and are statistically significant in all but one (see Tables 2.20 and 2.21). This supports the finding in previous studies that injury risks are a significant determinant of wages. The specification without the interaction variables implies a per injury premium of $12,680 (1978 dollars). When all of the interaction variables are included, this number becomes approximately $12,343 across all three samples.

The cancer coefficient is difficult to interpret. The variable is an index of exposure, not a measure of the incidence of cancer. It does show a significant positive effect on wages indicating that awareness of long term dangers may exist and is associated with higher wages. The awareness variable (KNOW) multiplied times the cancer variable is also positive and significant in all specifications.

Comments

These results are interesting for several reasons. The high levels of significance for the injury risk variable across all of the specifications provide further support for the existence of wage-risk differentials. The inclusion of both job characteristic and site characteristic variables in a more general wage model should help to reduce omitted variable bias. The use of the real wage variable (i.e., nominal wages adjusted for cost of living across SMSAs) should reduce the measurement error in that variable.

Another important result of the study is that workers are not only influenced by the risks of injury on the job but may also be sensitive to other health risks including those with long latency periods. The index of exposures to carcinogens was a significant determinant of wages in all equations. Interpretation of the KNOW variable as a measure of

Table 2.20

Estimated Real Wage Models Without Risk Interaction Variables, From V. K. Smith (1982)

	Full Sample	Male	Female
Intercept	.3411 (6.15)	.6512 (8.98)	.2021 (2.30)
EDU	.0244 (3.88)	.0300 (4.06)	.0283 (2.60)
$(EDU)^2$	.0013 (5.05)	.0010 (3.30)	.0009 (2.13)
POTEXP	.0261 (32.44)	.0309 (25.67)	.0181 (15.94)
$(POTEXP)^{2(a)}$	-.0455 (-26.62)	-.0532 (-22.26)	-.0301 (-11.91)
Race (white = 1)	.0560 (5.85)	.1118 (8.66)	-.0261 (-1.06)
Sex (male = 1)	.1663 (17.59)	-- --	-- --
Vet	.0749 (7.80)	.0359 (3.60)	-- --
UN78	-.0138 (-5.59)	-.0208 (-6.47)	-.0051 (-1.38)
Professional	.3471 (16.67)	.0871 (2.79)	.5650 (19.21)
Manager	.3740 (17.32)	.1411 (4.45)	.5225 (16.19)
Sales	.1491 (6.52)	.0019 (-0.05)	.2010 (6.36)
Clerical	.2001 (10.15)	-.1009 (-3.06)	.3924 (15.45)
Craftsman	.2646 (12.26)	.0171 (0.54)	.4495 (8.76)
Operative	.0780 (3.62)	-.1465 (-4.40)	.2375 (8.18)
Transport Equipment Operator	.1225 (4.68)	-.1180 (-3.35)	.3694 (5.38)
Labor Nonfarm	.0776 (3.25)	-.1288 (-3.81)	.2004 (3.99)
Service	-.0098 (-0.48)	-.2533 (-7.77)	.1702 (6.40)
Injury Rate (BLS)	.0114 (12.87)	.0113 (10.65)	.0117 (7.66)
Cancer Exposure Index	.0219 (2.76)	.0283 (2.77)	.0009 (0.72)
$TSP^{a)}$	.0871 (3.88)	.1120 (3.85)	.0675 (1.97)
Household Head	.1570 (18.08)	.2318 (16.96)	.0694 (6.02)
Union	.1832 (22.32)	.1730 (17.09)	.1857 (13.47)

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Table 2.20, cont.

	Full Sample	Male	Female
OJT·POTEXP	-.0012	-.0022	-.0010
	(-0.98)	(-1.60)	(-0.40)
Crime(b)	.0943	.0782	.1007
Rate	(4.60)	(2.94)	(3.24)
Sun	-.0015	-.0021	-.0002
	(-2.62)	(-2.79)	(-0.25)
Dual	-.0439	-.0408	-.0256
Job	(-2.28)	(-1.71)	(-0.82)
Know·	4.3032	3.8789	5.7079
Cancer	(6.01)	(4.70)	(4.22)
R^2	.460	.462	.322
s^2	.171	.160	.173
n	16,199	9,105	7,094

(a) coefficients have been scaled by 100 (i.e. reported = estimated x 100)

(b) coefficients have been scaled by 10,000.

*The numbers in parentheses below the estimated coefficients are t-ratios for the null hypothesis of no association.

Table 2.21

Estimated Real Wage Models with Risk Interaction Variables, From V.K. Smith (1982)

Variable	Full Sample	Male	Female
Intercept	.4038 (6.93)	.6443 (8.24)	.2328 (2.53)
EDU	.0234 (3.72)	.0304 (4.02)	.0254 (2.34)
(EDU)^2	.0013 (5.22)	.0010 (3.30)	.0011 (2.40)
POTEXP	.0263 (32.[illegible])	.0310 (25.78)	.0182 (16.05)
(POTEXP)$^{2(a)}$	-.0458 (-26.76)	-.0535 (-22.41)	-.0303 (-12.00)
Race (white = 1)	.0026 (0.13)	.0734 (2.55)	-.0329 (-1.10)
Sex (male = 1)	.1662 (17.58)	-- --	-- --
Veteran	.0749 (7.80)	.0363 (3.65)	-- --
UN78	-.0138 (-5.59)	-.0206 (-6.40)	-.0050 (-1.35)
Professional	.3499 (16.80)	.0903 (2.89)	.3678 (19.32)
Manager	.3741 (17.33)	.1426 (4.50)	.3184 (16.05)
Sales	.1479 (6.47)	-.0011 (-0.03)	.1981 (6.27)
Clerical	.1994 (10.11)	-.0975 (-2.96)	.3911 (15.39)
Craftsmen	.2625 (12.14)	.0184 (0.58)	.4432 (8.65)
Operative	.0741 (3.44)	-.1496 -4.50)	.2244 (7.69)
Transport Equipment Operator	.1236 (4.72	-.1134 (-3.22)	.3587 (5.22)
Labor Nonfarm	.0767 (3.21)	-.1293 (-3.82)	.1872 (3.72)
Service	-.0100 (-0.49)	-.2488 (-7.64)	.1683 (6.33)
Injury Rate (BLS	.0037 (1.47	.0122 (3.39)	.0100 (2.36)
Cancer Exposure Index	.0231 (2.91)	.0290 (2.84)	.0100 (0.81)
TSP^a	.0830 (3.70	.1084 (3.73)	.0615 (1.80)
Household Head	.1641 (10.90)	.3035 (11.69)	.1106 (4.74)
Union	.1174 (7.01)	.1035 (4.70)	.0971 (3.25)

Table 2.21, cont.

Variable	Full Sample	Male	Female
OJT*POTEXP	-.0017 (-1.38)	-.0022 (-1.65)	-.0021 (-0.82)
Crime Rate(b)	.0954 (4.66)	.0797 (3.00)	.1007 (3.25)
[illegible]	-.0014 (-2.47)	-.0020 (-2.71)	-.0001 (-0.11)
Dual Job	-.0426 (-2.21)	-.0400 (-1.67)	-.0220 (-0.73)
Know*Cancer	4.1318 (5.79)	3.8538 (4.66)	5.52 (4.07)
Injury*Race	.0070 (3.01)	.0044 (1.49)	.0012 (0.30)
Injury*Head	-.0001 (-0.67)	-.0084 (-3.24)	-.0064 (-2.06)
Injury*Union	.0070 (4.53)	.0073 (3.55)	.0133 (3.76)
R^2	.461	.464	.323
s^2	.171	.160	.173
n	16,199	9,105	7,094

---

*The numbers in parentheses below the estimated coefficients are t-ratios for the null hypothesis of no association.

(a) coefficients have been scaled by 100 (i.e. reported = estimated x 100)

(b) coefficients have been scaled by 10,000.

awareness of risks is more difficult. V. K. Smith uses it as a proxy for how well workers may be informed regarding the level of risks they face. He acknowledges that this information measure, based on provisions in union contracts, may be partially reflecting the effect of union bargaining power in negotiating the premium paid for job hazards. Another interpretation of the variable is possible. The KNOW variable may be correlated with jobs having higher risks. As job risks become greater, it may be more likely that union contracts will incorporate health and safety provisions. Thus, the inclusion of this information variable may be capturing part of the wage premium paid for risky jobs and not actually reflect any greater or lessor amount of risk awareness across industries. This would tend to bias downwards the estimates of the wage premium paid for hazardous jobs.

A final comment concerns the functional specification used by V. K. Smith. Early in the paper he states that, a priori, the shape of hedonic wage function is unknown; however, the functional forms presented in the paper all constrain the hedonic wage function to be convex with respect to injury risks. All of the specifications are semilog equations and, even if interaction terms are included, the hedonic wage function is constrained to be convex. Certain theoretic considerations, namely that risky jobs will attract workers who are less risk averse, and the empirical results of Olson (1981) indicate that a concave hedonic wage function is a likely possibility.

Comparison of the V. K. Smith results with empirical estimates of the value of a statistical life is difficult because the BLS injury rate he used did not distinguish between fatal and nonfatal injuries. The total wage premium estimated by V. K. Smith is approximately \$12,400 in 1978 dollars. This represents the premium paid for both fatal and nonfatal injury risks. Olson found the premium paid for risks of fatal injuries to be approximately 3.8 percent of wages and the premium paid for nonfatal injuries to be approximately 7.3 percent of wages, i.e., a ratio of approximately 1:2. The mean value of the BLS industry data shows that the probability of experiencing a fatal accident on the job is approximately 1 chance in 10,000. Using these parameters, a reasonable value for a statistical life from the V. K. Smith results would be (.0114 ÷ 3) x mean annual wages x 10,000 = \$466,500 in 1978 dollars. Again, this estimate is larger than the Thaler and Rosen (1975) results. A similar method of apportioning the risk premium estimated by Viscusi (1978a) shows a ratio between risk premium paid for fatal and nonfatal accidents of between 1:1 and 1:2.5. Bailey (1979) uses several ad hoc procedures to determine this ratio. His estimates range from 1:.75 to 1:1.75. Using these ratios for partitioning the wage-risk premium for all injuries into fatal and nonfatal risk premium would result in an even higher calculated value for a statistical life. If R. Smith (1974) is correct in his hypothesis that the wage premium reflects only the risk of fatal accidents since nonfatal accidents are covered by insurance and worker's compensation, then the coefficient on the risk variable could represent only the premium associated with the fatal risks. If this were the case, the value of life estimate from the V.K. Smith regression would be the coefficient on the risk variable .0114 x mean annual wages x 10,000, or $1.4 million.

2.3.7 R. Arnould and L. Nichols (1983)

This paper attempts to incorporate the effects of worker's compensation on wage-risk premiums. The basic premise of this paper is that the failure to take into account insurance, particularly an employer paid insurance such as workers' compensation, leads to a downward bias in previous estimates of wage risk premiums. The authors follow the same procedures as Thaler and Rosen (1975) with the addition of a variable to account for worker's compensation payments.

Data Sources.

The authors use the same risk data as Thaler and Rosen which allows risks to be identified by occupation, but does probably reflect nonwork as well as work-related risks. Data on individuals were from the public use samples of the 1970 Census of Population, 1/10,000 sample. (U.S. Department of Commerce, Bureau of the Census, Public Use Samples of Basic Records from the 1970 Census.) Data on worker's compensation were from: Rosenblum, H., Compendium on Workmen's Compensation, National Committee on State Workmen's Compensation, Washington, D.C., 1973.

Estimation Results.

Linear regressions were estimated with weekly wages as the dependent variable. Natural logs of wages and risk were also used, but not reported by the authors since they determined that the fit was no better. A squared risk term was negative but not significant.

The estimation results are given in Table 2.22. Value of life estimates were comparable to those of Thaler and Rosen. Without the effect of worker's compensation, this came to $200,000 per statistical life (1970 dollars). It was also estimated that workers were willing to forego an average of $22,998 in lifetime wages for the insurance coverage of wages lost due to work related injuries. The total value of a life is thus $222,998, 12% higher with the worker's compensation figured in.

Comments.

The use of the actuarial data poses the same problems as were discussed for Thaler and Rosen. Another problem is that Arnould and Nichols use only risk of fatal injury data with the explicit assumption that nonfatal risks are proportional. The accuracy of this assumption is very important since worker's compensation is more related to nonfatal than to fatal injuries. They also argue that it is appropriate to enter workers' compensation as exogenous since the coverage is set by legislative mandate. The workers' compensation variable was described as "effective rate of salary regained or other benefits payable for workers' compensation." If workers' compensation is properly thought of as a benefit, then its value should go on the left side in addition to wages.

2.4 SUMMARY OF THE HEDONIC WAGE STUDIES

The important question is simply what has been learned regarding the willingness to pay for reductions in risk from the hedonic wage studies that have been performed. A statement often made in the concluding sections of these studies is that there is substantial support for the hypothesis that wage differentials for job hazards do exist. The stated reason is that virtually all of the studies have found job risks to be significant and positively related to wages. Still, it is important to consider how confident a policymaker can be in using the numerical results from these studies. The establishment of causality

Table 2.22

Arnould and Nichols (1983) Regression Estimates of Wage-Risk Premiums
(Standard Errors are in parentheses)
Dependent Variable = Weekly Wages

	(1)	(2)
p	0.377	0.355
	(0.079)	(0.096)
p^2		-0.00008
		(0.0002)
pAGE	-0.005	-0.005
	(0.001)	(0.001)
pMARR	0.018	0.036
	(0.040)	(0.041)
pWHITE	-0.173	-0.155
	(0.063)	(0.064)
URBAN	1.879	0.957
	(4.275)	(4.345)
NORTHEAST	-4.186	-8.497
	(3.477)	(3.535)
SOUTH	-37.953	-37.702
	(3.697)	(3.771)
WEST	8.293	7.614
	(3.822)	(4.624)
AGE	5.162	4.584
	(0.552)	(0.569)
AGE^2	-0.048	-0.042
	(0.006)	(0.007)
EDUCATION	29.995	28.369
	(2.344)	(2.438)
EDUCATION^2	-1.166	-1.095
	(0.104)	(0.108)
MFG	-8.558	-9.572
	(3.297)	(3.345)

Table 2.22
Arnould and Nichols (1983) Regression Estimates of Wage-Risk Premiums
(Standard Errors are in parentheses)
Dependent Variable = Weekly Wages

(continued)

SERV	1.417	0.415
	(4.237)	(4.254)
WHITE	37.856	35.076
	(8.247)	(8.367)
FH	-2.596	-5.334
	(5.528)	(5.601)
HOURS	0.629	0.563
	(0.178)	(0.181)
FT	-13.863	-11.596
	(7.071)	(7.117)
UNION	11.575	11.836
	(2.466)	(2.039)
S	-459.975	-471.941
	(11.403)	(11.681)
R^2	0.907	0.908
DF	1811.	1811.

is always difficult in econometric studies and there exist several potential confounding influences in these wage studies. It is important to understand that a perfect empirical study can never be conducted and that even with weaknesses in the data or techniques, important insights may be generated. On the other hand, it would be a mistake not to recognize these shortcomings since they are important in the proper interpretation and application of the results. This section will summarize the empirical estimates and, in the context of these estimates, some of the controversial issues will be discussed.

2.4.1 Summary of Willingness-to-pay Estimates

A summary of the empirical estimates is presented in Table 2.23. Where studies considered more than one model specification, or segmented the sample, multiple estimates are reported. A judgemental "best" estimate is also presented that represents either the author's recommendation or a guess by these reviewers based on judgement and information presented by the study authors.

The estimates of the willingness to pay for a reduction of 1 chance in 10,000 in the risk of fatal accidents tend to cluster into two ranges--a \$40 to \$65 range and a \$400 to \$750 range. These estimates differ by roughly an order of magnitude. The studies that use risk data for occupations compiled by the Society for Actuaries (Thaler and Rosen, 1975; and Arnould and Nichols, 1983) find estimates of the value for reductions in risk in the low range, while studies using BLS data on risks by industries tend to estimate considerably higher values. One explanation commonly advanced to explain the differences in these estimates is that the fatality rates contained in the Society of Actuaries data are for high risk occupations. The mean annual risk of death in the occupations examined by Thaler and Rosen (1975) is approximately 11.0×10^{-4}, where the mean annual probability of a fatal accident in data obtained from BLS statistics is close to an order of magnitude lower (1×10^{-4} to 1.5×10^{-4}). One hypothesis advanced by Olson (1981), R. Smith (1979), Viscusi, (1978b) and Blomquist (1981) is that workers who place a lower value on safety are likely to be attracted to jobs with higher risks. In other words, workers who are least risk averse will be employed by these high risk jobs and estimates of the willingness to pay for marginal reductions in risk will be lower for these workers than for the average worker.

The implication of this hypothesis is that the hedonic wage-risk locus is concave (See Figure 1). This implies that wage premiums increase, but at a decreasing rate, as job risks increase. One inconsistency in the hedonic wage-risk studies is that while most authors appeal to the hypothesis of a concave wage-risk locus as one explanation of the differences between the estimates, in the empirical work all the studies (with the excep-

Table 2.23

Estimates of the Marginal Willingness to Pay for Reductions in Risks (expressed in May 1982 dollars)[a]

			Value of Reducing Risk of Death by 1 Chance in 10,000[c]		Value per Statistical Life[c]	
	Study	Mean Risk Level for the Sample[b]	All Estimates	Judgemental Best Estimates[d]	All Estimates	Judgemental Best Estimates[d]
1.	R. Smith (1974)	1.0 to 1.5	$750	($750)	$\$7.5 \times 10^6$	(7.5×10^6)
			1,320		13.2×10^6	
2a.	Thaler and Rosen (1975) w/o risk interaction terms[e]	11.0	$39		$\$3.90 \times 10^5$	
			50	($ 57)	5.05×10^5	(5.7×10^5)
			54		5.42×10^5	
			75		7.46×10^5	
b.	with risk interaction terms[f]	11.0	$1.40		$\$.14 \times 10^5$	
			$20		1.99×10^5	
			$27		2.75×10^5	
			$34		3.36×10^5	
3.	R. Smith (1976)	1.0 to 1.5	$322	($333)	$\$3.22 \times 10^6$	(3.3×10^6)
			344		3.44×10^6	
4.	S. K. Viscusi (1978b)	1.2	$146		1.46×10^6	
			223		2.23×10^6	
			266		2.66×10^6	
			344	($390)	3.44×10^6	(3.9×10^6)
			395		3.95×10^6	
			421		4.21×10^6	
			438		4.38×10^6	
5.	A. Dillingham (1979)	1.7	$34		3.4×10^5	
			40		4.0×10^5	
			41	($40)	4.1×10^5	(4.0×10^5)
			43		4.3×10^5	
			110		11.0×10^5	
6.	C. Olson (1981)	1.0	$760	($760)	7.1×10^6	(7.1×10^6)
7.	V. K. Smith (1982)	3.0[g]	$73 to $207[h]	($100)	$\$7.3 \times 10^5$ to 20.7×10^5	(1.0×10^6)
8.	Arnould and Nichols (1983)	11.0	$64	($64)	6.40×10^5	(6.40×10^5)

Table 2.23
Notes

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[a] Adjustments to 1982 dollars were made by using the consumer price indices for all items published by Council on Economic Advisors, Economic Indicators, December 1982.

[b] The risk level is expressed in annual deaths per 10,000 workers. The value should be viewed as an approximate figure since many of the studies reported risks in different units requiring transformation to common units.

[c] The multiple estimates are derived from the different model specifications examined. It was felt that presenting estimates from all the specifications is better than simply showing the range of estimates since one outlier can distort the range.

[d] The judgemental "best" estimate represents ant model specifications examined. It was felt that presenting estimates from all the specifications is better than simply showing the range of estimates since one outlier can distort the range.

[d] The judgemental "best" estimate represents a guess by these reviewers based on judgement and the information provided by the authors of each study.

[e] These estimates are from Thaler and Rosen (1975) equations that did not include interaction terms between risk and other variables.

[f] From specifications including interactions variables between risk and nonrisk variables.

[g] Calculated by assuming that .4 percent of all injuries are fatal. This is ratio for the BLS injury statistics is reported by Viscusi (1978b, p. 365).

[h] Calculated assuming the risk premium for risks of fatal injuries ranged from 33 percent to 100 percent of the premium associated with all risks.

tion of Olson, 1981) constrain the wage-risk locus to be either convex, through the use of a semilog specification, or linear. Only Olson (1981) allows for the existence of a concave wage-risk locus. He incorporates a squared risk term in the wage equation and finds the coefficient on the squared term to be negative and highly significant indicating that the function may, indeed, be concave. Constraining the hedonic wage-risk locus to be convex when it may actually be concave introduces the possibility of unknown biases in the estimated coefficient on the risk variable. Using essentially the same data as R. Smith (1976), Olson (1981) finds the inclusion of the squared risk variable results in substantially different estimates of the value of life. The Olson (1981) results indicate that the linear or semilog model used by the other studies will bias the value of life estimates either upward or downward depending on the risk level at which the value of life is estimated.

The estimates from Dillingham (1979) and V. K. Smith (1982) further confound the issue. The Dillingham study uses a different occupational risk data set and the V. K. Smith study utilizes a detailed model specification. The mean job risk levels for the workers in their samples are considerably lower than the Thaler and Rosen sample, but the estimated values of life are closer to the Thaler and Rosen estimates.

2.4.2 The Confidence in the Establishment of a Causal Relationship Between Job Risks and Wages

In assessing the confidence a policymaker can have in the relationships found between job risks and wages in the hedonic wage studies, there are several important issues. These include omitted variable bias, the direction of causality and the paucity of available data sets.

Potential Omitted Variable Biases

The omitted variable bias issue concerns whether the positive relationship between risks and wages found in these models might actually be due to a causal variable omitted from the model that is also strongly correlated with the measured job risk variable. If this were the case, then the job risk variable might not be a true causal variable but, instead, might be serving as a proxy for some variable omitted from the model. Even if there is a causal relationship between risks and the wage rate, omitting an important explanatory variable that is positively correlated with the risk variable will lead to an upward bias on the coefficient estimated for job risk.

One potential reason for omitted variable bias is the limited inclusion of job characteristic variables other than job risks. The majority of the studies include risk as the principal variable distinguishing different jobs. Other job characteristics were captured by using dummy variables for industrial groups (e.g., manufacturing, construction, or service industry) and sometimes for broad labor categories (e.g., operative, laborer or service worker). The important question is whether these dummy variables adequately capture the influence of job characteristics other than injury risks in explaining wage differentials.

A number of job characteristics other than risks could be hypothesized to affect wage differentials. These characteristics could include such things as repetitive work, physically tiring work, unpleasant working conditions (e.g., dirty, noisy, varying temperature and odors), and stressful conditions. Many of these factors could be considered as contributors to a risky environment or, if not causal, as joint products of those factors that contribute to a hazardous environment. The issue is then whether these estimated wage differentials are predominantly a response to safety concerns or are caused by the day to day stress and immediate physical discomfort. If job risks are always associated with poor working amenities, it may not be possible to disentangle factors associated with daily working conditions and pure safety hazards. This is particularly relevant when considering the potential transferability of these willingness-to-pay estimates to other nonwork related risks that may not be associated as closely with these disamenities. In sum, given the circumstances and job characteristics of the risky jobs that have been considered in these studies, it is not clear that these wage differential estimates reflect only the effects of risks. One could easily see that working in a pleasant environment at a job with a 1 in 10,000 chance of a work related fatality could require a very different wage premium than working in a noisy, dirty environment with varying temperatures at a job also associated with the same 1 in 10,000 risk of death.

The only wage-risk study that included other job characteristics was Viscusi (1978a) where the Michigan Panel Survey Data included questions relating to the size of the enterprise, whether the worker is a supervisor, whether the job requires the employee to work fast, and whether the job requires the worker not to make mistakes. The analysis showed a highly significant and positive relationship between wage differentials and jobs requiring the worker to work fast. This result indicates that important job characteristics could be overlooked in the wage-risk studies, leading to biased coefficients if the omitted characteristics are correlated with risks.

A data source that has commonly been used in other wage differential studies, predominantly studies examining the returns to education (e.g., Lucas, 1977; Bluestone, 1974; and Quinn, 1975) but that has largely been ignored by researchers conducting hedonic wage-risk studies, is the Dictionary of Occupational Titles (DOT) data tape compiled by the U.S. Department of Labor. The DOT provides data on job characteristics for tasks associated with over 13,000 occupations. The data include information on whether specific vocational preparation is required, whether higher levels of educational development are needed (a measure of the reasoning and intellectual development required by the job), whether it is nonsedentary, whether it requires physical strength, whether it requires repetitive or short-cycle operations according to set procedures, whether it involves working under stress, and whether the job has a bad physical environment. A bad physical environment is defined as having at least one of the following conditions: extremes of heat or cold, wet or humid conditions, sufficient noise to cause marked distraction, fumes, odors, toxic conditions, dust or poor ventilation. Since wage studies require individual data on wage rates, occupation, and personal characteristics, it would be possible to incorporate more detailed job characteristics in hedonic wage-risk studies. These DOT job characteristics have been shown to be significant explanatory variables in the wage model. The only study to use the DOT data and job risk data is C. Brown (1980); however, his sample was limited to a set of workers between the ages of 14 and 24, making extrapolation of the results difficult.

Consistently Significant Results Across Different Samples

One of the most often cited factors supporting the existence of wage-risk differentials is the consistent finding of risk as a positive and significant explanatory variable in wage models. Although persuasive evidence, this fact must be tempered by the realization that many of these studies used the same or very similar data sets and therefore cannot be viewed as independent verification of the existence of a risk related wage differential.

At a minimum, two sets of data are required for a hedonic wage-risk study: individual data on wage rates, and occupation and personal characteristics; and data on injury risks. All but one of the studies* have used one of two sources of data on worker risks--BLS data on injuries by industry or the 1967 Occupation Study of the Society of Actuaries. As discussed in the previous sections, both data sets have certain drawbacks. The BLS average death and injury data aggregated by industry introduces measurement error into the matching of risks to a specific individual's occupation. Job risks within an industry vary substantially across different occupations. The data compiled by the Society of Actuaries includes data on death rates for individuals employed in different occupations, but does not distinguish between job related and nonjob related fatalities. To the extent that the risk data from these two sources are biased or are correlated with important, but omitted, explanatory variables, the results of all of the studies will likely suffer from similar biases.

2.4.3 Summary of the Theoretic and Statistical Issues Raised by the Hedonic Studies

A number of theoretic and statistical issues are raised by the hedonic wage-risk studies that have been performed. Table 2.24 lists several of these issues. Issue #1 concerns the potential for omitted variable bias. This was discussed in some length in Section 2.4.2, and remains an important issue. The key question is whether the job risk variable might be serving as a proxy for an important, but omitted, explanatory variable. This would result in possibly artificial, or biased, estimated relationships between job risks and wages. This is an important issue due to the very limited number of job characteristics included in most of the hedonic specifications.

The second issue listed in Table 2.24 concerns the potential biases in the job risk data sets. One of two data sets have been used in all but one of the studies. Each data source has potential problems. The BLS data supply only average injury rates by industry, ignoring the substantial variation in accident rates for different occupations within an industry. The 1967 study by the Society of Actuaries of differential mortality rates across occupations does not distinguish between job related and nonjob related accidents.

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* Dillingham (1979) compiled injury incidence data from the State of New York Workman's Compensation Board.

Table 2.24

List of Issues and Controversies Present in the Hedonic Wage-Risk Literature

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1. The potential for omitted variable bias: Are additional job characteristic variables and location specific variables necessary to control for other factors that influence wage differentials?
2. The potential biases in the job risk data sets.
3. Specification of the correct functional form (i.e., linear, semilog (convex), risk-nonrisk interaction variables, or squared risk variables (which allows the wage risk locus to be convex or concave).
4. The paucity of appropriate risk data sets (i.e., most studies have used one of two available data sets).
5. The functioning of the labor market with respect to safety.
6. The separation of the estimated wage premiums into compensation for risks of fatal accidents and compensation for nonfatal injuries.
7. Are wage rates adequate for the estimation of risk related differentials in total worker compensation which may include wage and nonwage components as well as worker compensation and life insurance?

The third issue concerns the a priori specification of the wage function to be estimated. In spite of theoretic and empirical evidence that the hedonic wage risk locus may be concave, all but one of the studies have constrained the function to be either linear or convex. If the correct function is concave over the relevant range of risks, then the estimated coefficients will be biased in an unknown direction.

A fourth issue is the paucity of data sets containing information on the risks of injury for different jobs. Ideally, the wage or earnings equation should be estimated with data on individual workers. Such data are available for income, occupation, age, education, and other characteristics of the individual worker (many studies have used U.S. Census or Current Population Surveys), but data for on-the-job risks are more difficult to obtain. In general, these have been taken from other sources and matched to the individual data. One would like to look at the significant coefficients obtained by each of the eight or nine studies as strong evidence for the existence of risk related wage differentials. Although persuasive, this evidence must be tempered with the understanding that the data sets used in these studies are not independent. Further, similar techniques using the different data sets tend to give divergent estimates.

A fifth consideration concerns whether the labor market operates efficiently with respect to wage rates and safety. The underlying assumptions are that workers act as if they accurately perceive the risks associated with different jobs and appropriately account for these risk differentials in their choice of job. An additional assumption is that the labor market is free of structural constraints that might prevent workers from changing jobs. Labor market conditions such as the level of unemployment could also influence the estimates. The hedonic approach assumes that the market is in equilibrium.

Tests of these underlying model assumptions have been limited. This is particularly true for the assumption that all workers accurately perceive the risks associated with different jobs. Viscusi (1978a and 1978b) presented information on whether the workers in his sample considered their jobs dangerous. This dummy variable was positively correlated with the BLS data on industry injury rates, but certain anomalies were present. In particular, the fraction of workers in the most dangerous industries that rated their jobs as dangerous was less than the fraction of workers in lower risk jobs who considered their jobs dangerous.* The data compiled by Viscusi (1978a) are shown in Table 2.25.

An interesting potential violation of the assumptions of an efficiently operating labor market with respect to safety would involve the unequal distribution of information on job risks across workers. This could result in some workers overestimating the risks associated with specific jobs, some workers underestimating the risks of specific jobs, and some workers with accurate perceptions of job risks. Even if this job risk information is randomly distributed across workers, a bias in the estimated risk coefficient can result. In a process somewhat similar to the market for lemons (see Varian, 1978, p. 232), workers who underestimate job risks will gravitate to the riskier jobs, while workers who overestimate job risks will tend to accept lower risk jobs. If this is true, the use of actual risk data in hedonic wage-risk models rather than the employed workers' perceived job risks will bias the estimated wage premium downward. This results from the firm having only to offer the wage premium necessary to attract the marginal worker.**

The sixth issue listed in Table 2.24 concerns whether the wage premium can be separated into a premium associated with fatal risks and a premium for nonfatal risks. An ability to distinguish between these two willingness-to-pay values would improve the policy relevance of the estimates and the transferability of the estimates to nonwork related safety improvements. Some empirical data exist but the multicollinearily between the fatal and nonfatal accidents tends to confound the results. Many studies have used only fatal injuries with the explicit (or implicit) assumption that these are correlated with nonfatal injuries and can therefore represent both. Other studies have used as risk variables the frequency of nonfatal accidents, distinguishing in some cases between temporary and permanent disabilities, or the number of workdays lost. None of these measures is an exact measure of the risks of pain, inconvenience and decreased freedom of activity that would represent the loss of utility to the injured individual. Also, it is likely that worker's compensation will at least partially compensate workers for nonfatal accidents, thereby reducing the wage premium necessary to attract workers to industries

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* This might result from workers in riskier jobs being less risk averse and, therefore, they judge their jobs as not dangerous.

** Also, it must be true that only a small fraction of the total work force is employed in each job.

Table 2.25

Danger Assessments and Injury Rates from Viscusi (1978a)

Injury Rate[a]	Fraction of Workers in Each Interval Who Consider Their Job Dangerous	Percent of Workers in the Sample in Each Interval
0 to 5	.237	50.4
5 to 10	.426	17.8
10 to 15	.472	7.6
15 to 20	.534	7.7
20 to 25	.678	6.2
25 to 30	.657	7.0
30 to 35	.636	1.2
35 to 40	.600	1.5
40 to	1.000	0.6
		100.0

[a] disabling injuries per million hours worked

with high risks of nonfatal injuries. Since most hedonic studies have neglected the role of worker's compensation, using wage differentials to estimate the willingness to pay to avoid nonfatal accidents will be biased downwards.

The seventh and final issue listed in Table 2.24 concerns whether the use of wage rates rather than total compensation (wage and nonwage) is adequate for the estimation of risk related wage differentials. The most obvious problem is that worker's compensation and other insurance benefits may compensate the worker for incurring risks, a compensation that will not show up in wages. Ignoring other nonwage benefits may distort the estimation of wage-risk premiums if such benefits have any tendency to vary with the level of risk to which the worker is exposed. Ideally, a measure of the total value of a worker's wage and nonwage compensation should be used in these estimations. The importance of this measurement error is not apparent from the studies completed to date.

Applicability of Wage-Risk Results for Environmental Policy Decisions

Even if the wage-risk tradeoff is an accurate description of behavior in the labor market, it may not be directly applicable to environmental policy decisions. EPA must make decisions concerning the expenditure of resources to improve or protect public health and safety. A useful input for these decisions would be how much such protection is valued by the public. Wage-risk studies may be able to provide such input in some circumstances, but several issues must first be addressed.

Wage-risk premiums that are observed in the market are the result of the interaction of both supply and demand. They, therefore, reflect willingness-to-accept compensation for marginal changes in risk only at the risk level at which the individual is observed. This is primarily because preferences, in this case degree of risk aversion, cannot be assumed to be constant across all workers. Suppose worker A is observed working at risk level R1 with associated risk premium W1 and worker B is observed at risk level R2 with associated risk premium W2. (This example draws on Rosen, 1979). We can say that W1 reflects worker A's willingness-to-accept compensation for incurring risk R1, but unless worker A and worker B are identical, we cannot say that W2 reflects the compensation that would be required to induce worker A to accept risk level R2. This is because the wage-risk tradeoff does not map out an individual's willingness-to-accept compensation for many different levels of risk. It only indicates the individual's willingness-to-accept compensation for the level of risk at which he is observed. Figure 2.1 illustrates this point. The function W(P) is the observed tradeoff between risks and wages. The compensation (Wy*) required to get individual Y to accept the risk (Pz) that individual Z accepts is not the same as the compensation that Z is observed to accept (Wz) for tolerating risk Pz. The difference between Wz and Wy is not, therefore, a measure of an individual's willingness-to-accept compensation for an increase in risk from Py to Pz.* Using the market determined tradeoff to estimate the value of changes in risks will tend to understate the value of preventing increases in risks (by giving Wz - Wy rather than Wy* - Wy) and overstate the value of decreases in risks.**

Another concern is whether the nature of the risks involved on the job are comparable to those associated with a specific policy question. Individuals may not be concerned only with the probability of death, but the way which that death is likely to occur. The risk of falling twenty stories while cleaning windows may not be considered equivalent to the risk of a slow, painful death from cancer, even if the probabilities of each of these occurrences are equal. Most wage-risk studies have used measures of the frequency of fatal accidents on the job. Some have also used frequencies of nonfatal accidents. The probabilities of these fatal accidents are generally in the range of 1 chance in 10,000 and constitute a very small percentage of all work-related accidents. Of the work-related accidents considered by Viscusi (1978), 96.7 percent involved temporary total disability, 2.0 percent involved permanent partial disability, and .4 percent involved fatal accidents.*** R. Smith (1974) cites the National Safety Council analysis of work injuries which found that 22.6 percent were the result of handling objects, 20.4 percent were due

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[*] None of the wage-risk studies have attempted to estimate the willingness-to-accept compensation for risk functions that would be required to predict values for nonmarginal changes in risks. This next step is being explored, however, in the applications of hedonic price theory to the housing market. Mendelsohn (1982) has developed a technique for estimating the demand for a housing characteristic as a second step after estimating hedonic price functions for housing. By making use of spatial variation in the housing market and differences in hedonic prices faced by individuals who are employed in different loctions, he is able to examine how similar individuals respond to different prices, making estimation of the demand for the characteristic possible.

[**] Freeman (1979b), pp. 143-147) discusses the approximations that could be made from a hedonic price function and the direction of the biases that are likely to occur from the alternative approximations.

[***] From Bureau of Labor Statistics data and definitions.

to falls and 13.6 percent involved being struck by falling objects. Although work-related illnesses do occur, such as respiratory diseases, cancers, and acute poisonings caused by exposures to toxic and carcinogenic substances on the job, these are not the types of risks that are typically addressed in wage-risk studies. Since EPA is often concerned with nonfatal and fatal effects of pollutants that may be of a very different nature than on the job accidents, estimates of the value of life and safety from wage-risk studies may not be transferable.*

Wage-risk studies examine the tradeoffs made between risks and income for a certain segment of the population. At best, this segment includes only members of the employed labor force, thus underrepresenting children, elderly, women and others. In practice, the studies often look at an even smaller segment of the population by sampling only male workers, full-time workers, or blue collar workers. If we expect significantly different valuations on life and safety across different population groups, the valuations estimated for one group cannot be extended for the general public or for other specific groups expected to be affected by a pollution control decision. Again, empirical analysis is needed to determine the nature and extent of differences in valuations of life and safety across the population.

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* If more information were available concerning the differences in the way people value different risks, it would be possible to say that premiums for on-the-job risks represent an upper or lower bound. There is some evidence, for example, the involuntary risks are considered less tolerable than voluntary risks, but the evidence is as yet inconclusive. It would also be necessary to know how workers differ from nonworkers in the way they value risks.

3.0 CONSUMER MARKET STUDIES

Individuals make tradeoffs in their lives between risks and benefits in the consumption of many goods and services. Studies of these choices may be able to reveal the implicit valuation that people are placing on these risks. This approach is based on the presumption that individuals will maximize utility by choosing to accept risks up to the point where the expected benefits of accepting these risks just equal the expected costs of the risk. If the benefits can be quantified, then the implicit valuation on the risk is revealed. Just as with the wage-risk studies, the validity of these kinds of estimates depends on people having accurate perceptions of the risks that alternative activities entail. Two types of risks have been examined in the three studies reviewed here--risks of automobile accident fatalities and risks of residential fire injuries.* The studies are described and the results summarized individually below. The overall effectiveness of the approach, particularly as it compares with the wage-risk approach, is discussed in the summary section.

3.1 DARDIS (1980)

This study used information about how much people pay for smoke detectors to infer how much they are willing to pay to reduce the risk of fatal and nonfatal hospitalized injuries due to residential fires. This was based on a simple willingness-to-pay model that illustrates that the loss in utility associated with a small increase in risk can be translated into monetary terms by measuring the amount of wealth necessary to compensate the individual for the increase in risk. The model shows that this compensating variation can be combined with a change in risk of death to yield value of life estimates for small changes in risks. With the assumption that willingness to pay for smoke detectors is an example of such a compensating variation, the author presents the following formula for estimating the implicit value of a life.

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* A third type of risk is examined in Portney (1981). He suggests a methodology for estimating the value of reduced risks of mortality by examining premiums paid for homes in neighborhoods with lower air pollution and the resulting expected reduction in risk of death associated with the lower pollution level. This is an interesting approach but would be more complicated to apply than his illustration suggests. An observed air quality premium can only be interpreted as the willingness to pay of the household that has chosen to pay that premium. It would therefore be necessary to use the actual housing premium and air pollution level at which the household is observed in order to calculate the implied value of life. Portney points out the additional problems of separating aesthetic, morbidity and mortality components of the air quality premium.

$$z = bw'x$$

$$b = (z)(w'x)^{-1}$$

where

z = annualized cost of smoke detectors

b = value of a life

w' = weighting factor representing the individual's attitudes towards death or hospitalized injury

x = changes in the probability of death or hospitalized injury due to purchases of smoke detectors

This formula presumes that nonhospitalized injuries are not important and that property damage is adequately covered by insurance.

No information was available to suggest an appropriate weighting scheme for fatal versus nonfatal injuries, so three possible weighting schemes were selected to test the sensitivity of the estimates. Scheme 1 assumed that fatal injuries were twice as important as nonfatal injuries; Scheme 2 assumed that fatal injuries were ten times as important; and Scheme 3 put zero weight on nonfatal injuries. The author suggests that this range probably bounds the true weights.

Data Used

An annualized cost of smoke detectors was calculated from the Sears Roebuck and Company catalog prices assuming a life expectancy for the smoke detector of ten years and an average of 1.5 smoke detectors for households who own them. Two discount rates were used--5 percent and 10 percent. These data and calculations are shown in Table 3.1.

TABLE 3.1

Annualized Costs of Smoke Detector per Household

Source: Dardis, 1980

($1976)

Time Period	Sales[a] (Million)	Purchase Price	Annual Operating Costs	Annualized Costs[b] 5% Discount Rate	Annualized Costs[b] 10% Discount Rate
1974	1.8	$51.69	$7.00	$19.15	$21.37
1975	4.0	50.86	7.00	18.99	21.17
1976	7.5	39.65	1.57	9.75	11.65
1977	11.5	25.74	1.57	7.04	8.25
1978	10.0	17.40	1.57	5.42	6.21
1979	10.0	11.85	1.57	4.34	4.86

The change in risk associated with the use of smoke detectors was based on 1976 estimates of residential fire deaths and injuries from the National Fire Protection Association and the National Fire Prevention Control Administration, and the U.S. Consumer Product Safety Commission. There were slightly more nonfatal than fatal injuries, a much smaller ratio than for occupational risks or traffic accidents. Smoke detectors were estimated to be 45 percent effective against preventing death and 30 percent effective at preventing injuries. The author cites personal communication with R. W. Bukowski, National Bureau of Standards, for this estimate. Also, only 80 percent of installed smoke detectors were assumed operational at any one point in time. Given the number of households in 1976 (74 million), the reduction in annual risks of death associated with smoke detectors was calculated at 3.16×10^{-5} and the reduction in annual risk of injury at 2.26×10^{-5}. These calculations assume only one death or injury per household per residential fire. The author argues that the data indicate that such occurrences are dominant. For 1976, approximately 10 percent of all households had operating smoke detectors. By 1979, this had increased to over 40 percent (with 77 million households in 1979). Purchases due to local or state ordinances were excluded so this reflects a minimum of the percentage of U.S. households protected.

Results

The value of life estimates, in 1976 dollars, obtained from these calculations are shown in Table 3.2. Weighting scheme 1, for example, takes nonfatal injuries to be half as important as fatal injuries. The annualized smoke detector cost is therefore divided by the expected decrease in deaths plus one half the expected decrease in injuries. For 1974, using the 5 percent discount rate, this calculation is \$19.15 / .0000316 + 1/2(.0000226) = \$446,387. The value of life estimates range from \$606,013 to \$676,266 for households who purchased smoke detectors in 1974 to \$137,342 to \$153,797 for those who purchased them in 1979 when nonfatal injuries were given no weight. When nonfatal injuries are weighted at half of fatal injuries, these estimates fall to \$446,387 to \$498,135 and \$101,165 to \$113,287 respectively. The ranges result from different interest rates used in calculating the annualized price of smoke detectors.

TABLE 3.2

Value of Life Estimates

(1976 dollars)

—Annual *b* Values from Purchases of Smoke Detectors
(5 Percent Discount Rate)

Time Period	Weighting Scheme 1	2	3
1974	\$446,387	\$564,897	\$606,013
1975	442,659	560,177	600,949
1976	227,273	287,611	308,544
1977	164,102	207,670	222,785
1978	126,340	159,882	171,519
1979	101,165	128,023	137,342

—Annual *b* Values from Purchases of Smoke Detector
(10 Percent Discount Rate)

Time Period	Weighting Scheme 1	2	3
1974	498,135	630,383	676,266
1975	493,473	624,484	669,937
1976	271,562	343,658	368,671
1977	192,308	243,363	261,076
1978	144,755	183,186	196,519
1979	113,287	143,363	153,797

Comments

The interpretation of these estimates needs some elaboration. They are derived from prices paid for smoke detectors over a time period during which prices fell due to technological improvements. Figure 3.1 depicts the changes in price of smoke detectors as supply shifts, assuming that demand has remained stable.* The demand for smoke detectors can be thought of as the demand for the reductions in risks of fire injuries. The aggregate demand curve will be downward sloping as less risk averse households will be willing to purchase smoke detectors at lower prices, hence increasing the total number purchased as prices fall. The observed market price at any one point in time can be interpreted as the willingness to pay to reduce risks of fire injuries only for the household on the margin. Those who would have purchased the detectors at a higher price would be associated with a higher value of life. Also, the use of the purchase price of smoke detectors to reflect the consumer's willingness to pay for reductions in risks of fire related fatalities and injuries ignores the time and effort involved in learning about, purchasing and installing a smoke detector. Ignoring these costs will cause an understatement of willingness to pay to reduce risks of fire related fatalities and injuries. As a result, the $450,000 to $680,000 estimate from this study is a lower bound for households who purchased smoke detectors in 1974.

In theory, the willingness to pay for a reduction in risk equivalent to a statistical life for households that did not purchase smoke detectors is below these estimates. However, given the recognized lags in the adoption of new consumer products one would be hesitant to conclude that all households that had not purchased smoke detectors placed a lower value on a statistical life than the Dardis' estimates. As a result, the Dardis estimates can be interpreted as the willingness to pay for a reduction in risk by the marginal consumer, but there are some consumers who would have been willing to pay a higher price for smoke detectors and, therefore, place a greater value on the reduction in risk. Also, since 60 percent of all households have not purchased a smoke detector, some households are likely to place a lower value on the reduction in risk, which would lead to a lower value of life estimate. With this perspective, the Dardis estimates provide a

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* Demand probably did not remain fixed over this period, but this does not affect the observation that the purchase price reflects willingness to pay only for the marginal consumer.

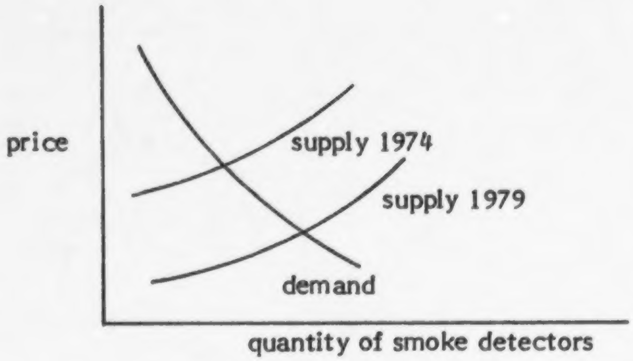

Figure 3.1: Supply and Demand for Smoke Detectors

possible benchmark for determining a reasonable range for the value of a life but they do not provide us with an estimate that can be directly used in policy evaluation.

3.2 BLOMQUIST (1979)

This study examines consumers' willingness to take the time and suffer the inconvenience of using their seat belts in order to reduce the risk of fatal and nonfatal injuries. These actions imply a specific dollar value for the reduced risk and hence a value of life for the marginal belt user.

The author defines a utility maximization model that incorporates the probability of survival in the present and future periods as well as the opportunity to spend resources on life saving and injury avoiding activities. From this model he derives the utility maximizing condition that the value of the marginal product in reducing mortality plus the value of the marginal product in reducing injury loss equals the marginal cost:

$$P'V - R'I = K$$

where

V = the value of life, i.e., a value of a unit change in the probability of survival

P' = the change in the probability of survival, i.e., the marginal physical product in reducing mortality

R' = the (negative) change in probability of nonfatal injury, i.e., the marginal physical product in reducing injury

I = the present value of the avoided morbidity loss

K = the cost of the safety enhancing activity, i.e., the dollar cost plus the monetary worth of the disutility cost

Probit analysis is used to examine the seat belt use decision as a safety enhancing activity. It is hypothesized that

$$S = BX + U$$

where

S = an index of seat belt use benefits; seat belts are used if $S > 0$ and not used if $S < 0$

B = a vector of fixed parameters

X = a vector of measurable benefit and cost variables

U = a random term for unobservable differences among individuals with $E(U) = 0$ and $E(U^2) = \sigma^2$

The probit model estimates a standardized index such that

$$S^* = B^*X + U^*$$

where

$S^* = S/\sigma$, $B^* = B/\sigma$, and $U^* = U/\sigma$.

For the average driver, where $\overline{X}$ are the independent variables evaluated at the means, the average standardized net benefit of seat belt use, $\overline{N}$, is

$$\overline{N} = B^*\overline{X}$$

Thus

$$(\overline{P'}V - \overline{R'I} - \overline{K})/\sigma = B^*\overline{X} = \overline{N} \quad (1)$$

where the bars indicate average values. With estimates for $\overline{P'}$ and $\overline{R'I}$, the value of life is still not revealed by this equation because $\overline{K}$ and σ are both unknowns as well as V. The author therefore makes several assumptions and calculations to obtain a lower bound for V.

First, in order to obtain an estimate of σ, he suggests that the money cost of using seat belts is made up entirely of the time cost, when installation costs are ignored. If time costs are a linear function of the wage, then

$$q = awt$$

where q is the dollar cost of seat belt use, "a" is constant, w is the wage and t is the time that seat belt use requires. He uses estimates of "a" from previous studies and an estimate of t to obtain a value of $\partial q/\partial w$, which is the relationship represented by the non-standardized wage coefficient B_w. From this it follows that

$$B^*_w = at/\sigma$$

since $B^*_w = B_w/\sigma$. Thus

$$\sigma = at/B^*_w.$$

Equation (1) is now down to two unknowns: the remaining part of K that represents disutility cost and V. The author proceeded by using the probit equation to estimate what standardized net benefits of seat belt use would be if time and disutility costs were zero. If this is represented by N_{all} and $\hat{\sigma}$ represents $at/\hat{B}^*_w$ then

$$(P'V - R'I)/\hat{\sigma} = N_{all}$$

N_{all} equals 2.326, the 99th percentile value of the standard normal distribution, because the dependent variable of the probit equation is a standardized variable. Solving for V yields

$$V = (N_{all}\,\hat{\sigma} + R'I)/P'$$

This estimate of V is a lower bound because it represents the minimum amount that would induce 99 percent of all drivers to use seat belts. There are others who are currently using seat belts or who would use seat belts at costs less than what they currently face but greater than zero. Both these groups could be placing a higher value on life than this estimate of V.

Data Used

The data for seat belt use and other individual characteristics were from the Panel Study of Income Dynamics, 1968-1974 (Survey Research Center, Ann Arbor: University of Michigan, Institute for Social Research, 1972, 1973 and 1974). Seat belt use was measured in 1972 and takes on a value of one if the driver said he used the seat belt all of the time and zero if he never used it. Part time users and passengers were ignored. Since income data were used in the estimation, the sample was limited to drivers who worked in 1972.

The time required for fastening, adjusting, and unfastening seat belts was measured by the author in a time and motion study. The effectiveness of seat belt use in preventing fatalities in the event of an accident was taken to be .50 and with respect to nonfatal injuries was .25. (These were from B.J. Campbell, Brian O'Neill, and Beth Tingley, "Comparative Injuries to Belted and Unbelted Drivers of Subcompact, Compact, Intermediate and Standard Cars," Paper presented at the Third International Congress on Auto Safety, San Francisco, July 15-17, 1974, and Forrest H. Council and William W. Hunter, Seat Belt Usage and Benefits in North Carolina Accidents, Chapel Hill, N.C.: Highway Safety Research Center, 1974.) The annual risks of fatal and nonfatal injuries in automobile accidents were 3.027×10^{-4} and 1.392×10^{-1}, respectively. (These estimates were based on data from: the National Safety Council, Accident Facts, Chicago, 1973; The U.S. Department of Transportation, Federal Highway Administration, Fatal and Injury Accident Rates. Washington, D.C.: G.P.O. 1973; and the Illinois Department of Transportation, 1974 Accident Facts Springfield, Illinois 1975.)

The average dollar loss for nonfatal injuries, $\overline{I}$, was taken as $850 for labor productivity loss plus $100 for pain and suffering. The latter amount the author explained was arbitrary. (These estimates were from U.S. Department of Transportation, National Highway Traffic Safety Administration, Proceedings of the Fourth International Congress on Automotive Safety Washington, D.C., G.P.O. 1975).

Results

The estimated average annual time expenditure on seat belt use was 3.342 hours. Using the estimated B^*_w and an "a" of .40, $\hat{\sigma} = (.40)(3.342)/.0796 = 16.79$. $\overline{P'}$, the average change in risk of death associated with seat belt use, was 50 percent of the probability of a fatal injury: $(.5)(3.027 \times 10^{-4}) = 1.514 \times 10^{-4}$. $\overline{R'}$, the average change in risk of nonfatal injury associated with seat belt use, was 25 percent of the probability of a nonfatal injury: $-(.25)(1.392 \times 10^{-2}) = -3.481 \times 10^{-3}$. $\overline{I}$ was \$950. Thus:

$$V = (2.326)(16.79) + (-3.307) / (1.514 \times 10^{-4}) = \$236,107$$

The sensitivity of this estimate was tested by making some moderate changes in the assumptions behind several of these estimates. The result was a range of about \$147,000 to \$526,000 (1972 dollars).

Two income variables were used in the probit equation: hourly wages and present value of expected future income. It was hypothesized that these would have opposite influences on the likelihood of an individual using his seat belt. Wages had a negative coefficient, presumably because the value of time is greater for people with higher wages, thus reducing the likelihood of taking the time to use a seat belt. The coefficient for the present value of future earnings was positive, indicating that greater future earnings were associated with more seat belt use, as would be expected. The exact values of these probit coefficients are difficult to interpret because they are standardized. A bigger B^*_w in absolute value would, however, result in a smaller estimate of V. The coefficient for future earnings does not directly influence the value of life as it was calculated here, but it does indicate that value of life can be expected to increase as expected future earnings increase.

Comments

The calculation of the value of life in this study rests on several assumptions, each of which is subject to considerable error. The first of these was that the time it takes to buckle and unbuckle a seat belt is an important factor in determining whether the seat belt will be used. A second assumption was that the value of time is a fraction of the hourly wage. Transportation studies have found this result, but the evidence is mixed concerning the appropriate fraction of the wage to use. Blomquist ranges it from .3 to .5. If the true value of time spent buckling and unbuckling were the hourly wage itself, the estimated V would increase to $623,183 (1972 dollars). A third assumption was the value of nonfatal injuries. This estimate was based on medical costs plus an arbitrary amount for pain and suffering. This is not a theoretically correct willingness-to-pay measure of value. It could overstate or understate the true value by an unknown amount.

The study also assumes that individuals know the risks of death and injury while driving with seat belts fastened and driving without using seat belts. Further, the study assumes drivers choose to use or not use seat belts based on an implicit or explicit balancing of perceived costs against perceived benefits of seat belt use. Slovic et al. (1977) discuss the results of several surveys that indicate reasons for the low level of seat belt use. They suggest that the reluctance to wear seat belts may be due to the probability of death or injury on a single trip being too low to incite a motorist's concern. In addition, the small probability of accidents is continually reinforced by repeated safe driving experiences. They suggest that for very low risks, people act as if the risks are zero due in part to the disutility of worrying all the time. As a result, the decision to wear or not wear seat belts may be determined by whether or not the associated risks exceed the risk threshold that results in the individual taking action to reduce those risks. The existence of such a risk threshold would not necessarily change the equation used to predict seat belt use, unless it would imply a different set of explanatory variables. If the risk threshold is the primary determinant of seat belt use, it is possible that the estimated model is actually capturing the influence of variables that determine the risk threshold levels for different individuals. The most important problem that arises if this threshold theory is correct is that Blomquist's procedure for calculating the value of life is based on what benefits would have to be to induce drivers who are not currently using seat belts to use them. If in fact these drivers are acting as if the benefits are zero because the risks are less than their concern threshold, then this method does not estimate the value of life. In this case, the values estimated would be meaningless.

3.3 GHOSH, LEES AND SEAL (1975)

This study looks at the tradeoff people make in terms of time saved and increased risk in choosing a driving speed on the highway. Given the relationship between speed and accidents, and speed and fuel consumption, the authors derive a relationship between the optimal speed on British motorways and values of life and time.

They develop a model which says that the monetary benefits of driving faster are the monetary value of time saved minus the monetary value of the extra fuel consumed plus the (negative) monetary value of increased risk of casualties. The formula the authors derive for the optimal average driving speed is

$$S = \left(\frac{V \cdot P}{\frac{V \cdot Pg \cdot G}{R} + Px \cdot B} \right)^{1/2}$$

where

S = average speed of traffic
V = volume of traffic
P = value of a unit of time
Pg = price of a gallon of fuel
G = change in fuel consumption for a unit change in S
R = distance for which fuel consumption change was calculated
Px = cost per unit casualty (value of life for fatal injuries)
B = change in casualties for a unit change in S.

The relationship between casualties and speed is estimated in a linear regression. The relationship between fuel consumption and speed is taken from other studies. The monetary value of time is also taken from other studies. By taking the actual average speed as optimal and using these estimates of the other variables, the authors solved for the implied monetary value of preventing a fatal injury, Px.

Data Used

The highest value of time estimate that the authors used was equivalent to the 1973 wage rate. They also used fractions of this amount to test the sensitivity of results. They point out that time saved per vehicle may affect more than one individual if there are passengers.

They used monthly data for the period January 1972 to March 1974 on vehicle miles travelled, average speed, average sunshine, and casualties to calculate the relationship between speed and casualties. The relationship between fuel consumption and speed was assumed constant at speeds above 40 mph and was taken from the Transport and Road Research Laboratory. This was .052 gallons per m.p.h. for a distance of 100 miles. The price of fuel was 35p.

Results

The estimated relationship between casualties and traffic speed, volume, and weather was (t-ratios of the coefficients in parentheses):

$$\begin{array}{l} X = -1169.70 + 746.66\,V + 18.49S - 24.6\,W \\ \qquad\quad (5.16) \qquad (6.34) \qquad (4.46) \quad (2.69) \end{array}$$

where

X = casualties
V = volume of traffic
S = average speed of traffic
W = weather index.

The coefficient on S provides the value for B in the optimal speed formula. With a value of time estimate of £1 per hour (the approximate 1973 average wage), the authors calculate an implied value of life of £94,000 which converts to $230,394 in 1973 dollars. This was done by taking the actual average speed, 58.8 m.p.h., as the S in the formula for optimal speed and solving for Px. The authors do not provide enough information to recreate this calculation, but their major assumptions have been elaborated.

Comments

One of the most questionable assumptions upon which the optimal speed formula was based was that time saved is the only benefit of faster driving speeds. If there are other benefits of increased speed (such as the thrill), the true value of life may be much higher. The driver may be trading off other benefits of increased speed against the increased risk of death.

As with the Blomquist study, this study also relies on an assumption about the value of time. A lower value of time would mean a lower value of life from these calculations.

3.4 SUMMARY OF CONSUMER MARKET STUDIES

Table 3.3 summarizes the value of life estimates that have resulted from these three consumer market studies. In each case, the estimate is based on assumptions that may not be valid. Dardis used the price of smoke detectors as a measure of willingness to pay for the increased safety they provide. This is accurate only for the marginal consumer. Others may have substantially different willingness to pay than the market price. Blomquist explicitly estimated a lower bound. Ghosh, Lees and Seal assumed that the only benefit of increased driving speed is the time it saves. In each case the major assumptions tend toward an underestimate of the value of life. It is not surprising that the estimates are on the low side compared to many of the wage-risk study results.

The consumer market studies require several of the same assumptions and face several of the same problems as the wage-risk studies. They are based on the presumption that individuals make rational, well informed, utility maximizing choices with respect to risks. An important difference with consumer market studies is that we are looking at how much consumers will pay (or give up in terms of time and inconvenience) in order to reduce a particular risk. Wage-risk studies look at how much workers must be compensated in order to accept particular risks. Individuals' attitudes may be quite different in these two situations. Workers know that they are facing risks on the job that are earning profits for someone else. Since the benefits of accepting these risks accrue to someone else, the worker is likely to be unwilling to accept these risks without adequate compensation, and is likely to err on the side of cautiousness in his judgement about the magnitude of the risks he faces. With risks such as traffic accidents and residential fires, there may be more of a tendency for the individual to underestimate the risks with thoughts like it can't happen to me, or I'm a careful driver. In these cases the individual must take the trouble to buy a smoke detector, or fasten his seat belt, in order to reduce the risk. He must be convinced that the risk is troublesome enough for this to seem worthwhile, i.e., there may be a systematic bias in perceptions of risk between WTP and WTA situations.

As with wage-risk studies, consumer market studies face considerable data source limitations. Measures of risks that are available tend to be averages for large segments of the population. People will make choices based on the risks they perceive themselves to face, which may actually be quite different from the average risks. Risks of traffic

TABLE 3.3

Summary of Value of Life Estimates from Consumer Behavior Studies

Study	Initial Risk Level	Increment of Risk	Average Value Per Life	Value Per Life 1982 Dollars	Nature of Risk Examined
Dardis (1976$)	8.77×10^{-5}	3.16×10^{-5}	$189,049 to $294,968	$318,334 to $496,688	Residential fire fatalities
Blomquist (1972$)	3.027×10^{-4}	1.514×10^{-4}	$236,000	$540,747	Automobile accident fatalities
Ghosh, Lees and Seal (1973$)	Not reported	Not reported	$230,394	$496,966	Automobile accident fatalities on British motorways

accidents are not the same for all drivers in all parts of the country and neither are risks of fires the same for all residences. The benefits of accepting risks may be even more difficult to measure. For the Blomquist study, no measure of the disutility of seat belt use other than time was available. Ghosh, Lees and Seal also relied on a rather shaky assumption that the only benefit of driving faster is the time it saves. Dardis took the price of smoke detectors as the measure of the benefit that the smoke detectors provide, but this price also reflects other market influences.

These studies have done a reasonable job of developing credible models for the data with which they had to work, but data limitations and the uncertainty about the consistency of people's choices with respect to small changes in risks limit the general usefulness of this approach for environmental policy decisions, at least as far as these examples are concerned. The results of these studies do, however, confirm that people make tradeoffs between safety and other resources. They do not do everything they can in order to reduce a risk; the amount of resources that they expend in order to reduce risks is limited. Useful estimates for environmental policy purposes might be obtained through this approach if observable tradeoffs are being made for the kind of risks being considered, if the data are available and behavior consistency can be confirmed.

4.0 CONTINGENT MARKET APPROACHES

Contingent market approaches for valuing life and safety entail the use of surveys in which respondents are asked to directly or indirectly place dollar values on changes in risks of death or injury. They are called contingent market approaches because, for a good that is not normally traded on markets, a hypothetical market is posed to the respondent and he is asked what he would pay for the good, contingent upon the existence of such a market. This approach has received considerable attention recently for its potential in providing estimates of willingness to pay for environmental quality and other nonmarket goods. (See Brookshire et al., 1982, for an example of such an application and Rowe and Chestnut, 1982, for a detailed review of this technique as applied to the visibility impacts of air pollution.)

Contingent market approaches try to elicit, through the use of surveys, what tradeoffs people are willing to make between safety and income. Everyone wants better health and more safety, but the reality is that the amounts of time and money that people will expend in order to obtain better health and more safety are limited. In fact, people make tradeoffs all the time between increased risks on the one hand and monetary or other benefits on the other. For example, a decrease in traffic fatalities was observed when maximum speed limits were reduced to 55 mph, but still this speed limit must be enforced. Some people find that they are willing to incur the greater risk of fatal accidents, the higher fuel consumption, and the risk of receiving a speeding ticket in order to shorten their travel time and obtain the enjoyment of driving fast.* The challenge of the survey approaches is to elicit accurately the valuations on safety that are behind these kinds of choices.

The most widely applied contingent market approach is the contingent bidding method. In this approach, as applied to the valuation of risks, respondents are given information on current and potential alternative levels of risks in a particular activity. They are also given hypothetical markets that describe how payments are to be made or received by the respondents for changes in this risk. Next, they are asked to bid their maximum willingness to pay (WTP) or minimum willingness to accept compensation (WTA) to prevent or incur the change in risk. Respondents may be asked to pay for reduced risk through increased taxes, increased product costs for safety, and increased time spent in travel and the like. The bids are usually obtained through one of three approaches--posing an open ended WTP or WTA question, asking the respondent to choose a value from a payment card with numerous alternative payment amounts listed, or using an iterative bidding procedure where the interviewer asks if the respondent is willing to pay (or accept) a specific amount and then continues to change the amount until a maximum WTP (or minimum WTA) is determined. These surveys usually also ask related questions on perceptions and attitudes as well as socioeconomic characteristics of the respondent in order to identify the underlying determinants of the bids and to check their reasonableness.

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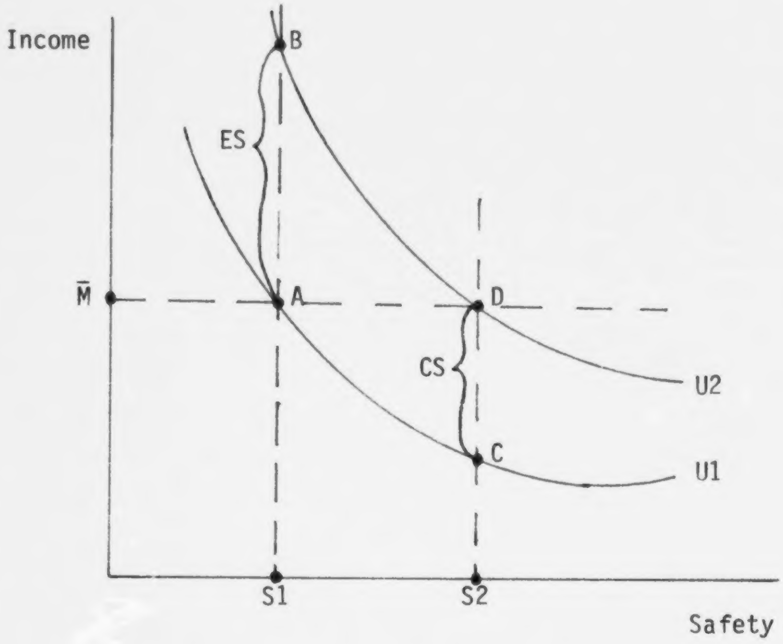
* Other factors may also be involved such as a change in the risks of driving fast since others now drive slower and changes in driving patterns due to increases in gas prices.

Another contingent market approach is the contingent ranked attributes technique. With this procedure, respondents are asked to rank various sets of alternatives in order of preference. Each alternative would include a level of risk and a payment of some sort so that the rankings would reveal a valuation without the respondent having to give dollar estimates directly.

These contingent valuation approaches are used to estimate a dollar measure of the change in utility that would be caused by the change in safety. This is illustrated with the use of an indifference map in Figure 4.1. Suppose that U1 and U2 are two indifference curves representing the tradeoffs between safety and all other goods, represented by income, that would keep the individual's utility constant. U2 represents an unspecified higher level of utility than U1. If the individual is at safety level S1 and income level $\bar{M}$, he is at point A with utility U1. If safety were increased to S2, his utility would increase to U2. This increase in safety results in the same utility increase as would an income increase of BA at safety level S1. We therefore say that BA is the maximum that the individual would be willing to pay to obtain S2. This is called the equivalent surplus measure because it represents the change in income that would be equivalent to the change in safety. A slightly different measure would be how much income would have to be reduced in order to bring the individual back to utility level U1. This is amount DC and is called compensating surplus because it is the amount that would compensate (in this case negatively) for the change in utility caused by the change in safety. If instead, safety were reduced from S2 to S1, DC would be the equivalent surplus measure and BA

Figure 4.1

CS and ES Consumer Surplus Measures


Income
B
ES
M̄
A
D
CS
C
U2
U1
S1
S2
Safety

would be the compensating surplus measure. Thus, the direction of the hypothesized change and the wording of the question—how much would you pay versus how much would you accept--determines whether the survey is eliciting equivalent or compensating surplus measures. These measures are not expected to be exactly the same and one is not necessarily better than the other. Previous contingent market approaches have found surprising and somewhat inexplicable differences between the two (see Rowe and Chestnut, 1982, for more on this).

Problems in Applications of Contingent Market Approaches

Economists have long been skeptical of survey approaches because they are suspicious that what people say they want, or are willing to pay for, and what they will actually part with money in order to obtain, are two different things. The challenge of contingent market approaches is to design a survey instrument that will effectively elicit the desired information. Valuations received with contingent market approaches have often varied substantially with small changes in the application of the technique and must, therefore be carefully designed and monitored. One of the most important problems encountered in these approaches is what sociologists and survey psychologists deal with in interview studies--designing questions so as to minimize perception errors and biased responses. Bidding methods ask respondents to reveal consumer surplus measures for hypothetical situations often not faced in a market place. Only estimates of their "true" values and predictions of what their behavior would be in the hypothetical situation and market, as they perceive it, can be reported. The reported values may well reflect the respondents "true" values estimated with a great deal of uncertainty, and subject to the influences inherent in the design of the survey instrument. These influences decrease the accuracy of responses and may yield biases in the valuation process. The evidence to date suggests that substantial inaccuracies and biases often result from hypothetical problems, the payment approach, and the bidding procedure employed.

Survey research has found that responses are most accurate when the questions are about topics or decisions that are familiar to the respondent, when the questions are realistic and credible, and when the time and inconvenience of answering the questionnaire is low. (See Crespi 1971, Erskin 1972, and Ajzen and Fishbein 1977.) This means that a question about willingness to pay for safety needs to be presented in a context in which the respondent can imagine having to make such a choice. For example, a question about how much the respondent would be willing to pay in higher automobile prices for improved or increased safety equipment in an automobile is probably much more effective than a question that simply asks how much the respondent would pay to increase his life expectancy by a specific number of years. In the first case, the payment mechanism is concrete and realistic and the choice is one that the respondent could imagine having to make, whereas the second one is vague and difficult to identify with.

The applicability of the contingent market approach to the valuation of risk depends on the ability of respondents to weigh the importance of small changes in risks. In most ordinary circumstances, the risks faced by individuals in any particular activity are very small. The average annual risk of fatality in an automobile accident is, for example, about .0003 (3 in 10,000), while for fatal accidents on the job for blue collar workers, it is about .0002 (2 in 10,000). People do make decisions in their lives that involve risks of these magnitudes and will expend time and money to reduce such risks by a small amount, but the survey questions must adequately communicate the nature and size of the change in risk being considered in terms of familar experience. Suggesting that the respondent imagine going from a risk of 10^{-6} to 10^{-5} of dying this year from some specified cause may not mean much. This could possibly be avoided by using bigger changes in risks, but probably only at the expense of introducing a very unrealistic scenario. Contingent market approaches, as well as the market approaches, could profit from a better understanding of people's attitudes and judgement processes about what risks are acceptable for what benefits. Although contingent market studies do not rely on interpreting observed behavior, understanding typical behavior and judgement processes with respect to risk would help the researcher pose more meaningful questions.

Usefulness of Contingent Market Approaches for Policy Analysis

When the problems in the applications of contingent market approaches for valuing changes in safety or risks are minimized or resolved, these approaches can provide useful input for environmental policy decisions. Contingent market approaches have the advantage of a great deal of flexibility. Constrained only by the necessary realism of the hypothetical scenarios, the approach can be structured to address the specific question at hand. It can therefore be used in circumstances when no appropriate market information is available. The approach is also easily and quickly implemented, but a careful survey effort can be expensive, especially if personal interviews are conducted.

Contingent market approaches can also be used in conjunction with questions about attitudes and opinions on environmental policy. Such information could help to verify the interpretation of contingent market responses and the results of actual market approaches. It may be that market distortions and lack of information prevent observed behavior from reflecting true preferences. Surveys might therefore provide better willingness-to-pay estimates. It may also be possible to have respondents describe tradeoffs they would be willing to make in other than dollar terms. They could, for example, be asked how much time they would spend to reduce the risk of a certain kind of accident. Although this approach would avoid the problem of requiring respondents to put dollar values on something they do not typically think of as a marketable item, the problem still remains of having to put dollar values on time or whatever measure is used if the results are to be used in benefit-cost analysis.

4.1 REVIEW OF CONTINGENT MARKET STUDIES

Five contingent market studies that have addressed questions of dollar valuations for changes in risks are reviewed here. These reviews focus upon the type and level of risks being evaluated, the effectiveness of the survey instrument and procedure, and the valuation results obtained. Some overall evaluative comments are offered for each study. A summary of the usefulness of these results and this approach for environmental policy decisions is provided at the end.

For the most part, these studies are best interpreted as tests of the survey instruments and procedures because the samples are often nonrandom or too narrow to provide estimates applicable for public policy analysis. They have not paid much attention to the emerging literature on contingent market approaches for obtaining estimates of values for nonmarket goods. Two of the studies conducted some pretests of their survey instrument, but all of them could have benefited from the refinements in survey design that have been evolving in other areas of environmental quality valuations.

The value of life estimates implied by the responses to these surveys vary widely both within studies and across different studies. The studies do indicate that most respondents were willing to put positive dollar valuations on decreases in risks and that they were willing to make the effort to answer these questions seriously and reasonably.

These studies point to several questions that should be addressed in future efforts. Refusals to participate in these surveys need to be explored. High refusal rates can lead to serious bias in a statistical analysis. The reasons for zero bids and extremely high bids need to be probed. These may reflect true preferences, but they may also reflect an objection to the question itself. People may be offended by the suggestion that they trade safety for money or may feel that life is sacred and not to be monetarily valued or that the time of death is predetermined and cannot be altered.* Understanding the reasons for these bids may help in deciding how to treat them in the analysis and may suggest different approaches for future surveys.

Another area that needs to be explored more carefully is how WTP changes for different changes in risks. This needs to be probed by reordering questions, by making sure the respondent understands the change in risk being valued, and by posing questions that change the initial level of risk but not the increment of risk being valued. Most of the studies that have examined different risk increments have changed both the risk level and the size of the incremental change in risk being valued. This has made it difficult to tell what is happening to the value of life as risk levels change.

4.1.1 Acton (1973)

This study examined programs that could be implemented to reduce the risk of fatal heart attacks. Most of the programs considered would increase the availability of assistance to heart attack victims, although some would involve screening to identify individuals with high heart attack risk. As part of the effort to evaluate the benefits of these types of programs, a survey was conducted in which respondents were asked to quantify how much they would be willing to pay for specific reductions in risks of heart attack fatalities.

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* The studies reviewed in Chapters 2 and 3 indicate that people do make these kinds of tradeoffs, but responses to some of the survey efforts indicate that they may not like to think about it in these terms.

Survey Instrument and Procedure

Thirty-two individuals were interviewed based on a random sample of households in three communities in the Boston area. The refusal rate was not reported for the community sample. Two other groups were also given the questionnaire, although a statistical sample was not taken. These were a group of trade union leaders and a group of upper level business executives. The two latter groups had higher average incomes than the community sample and were all male.

The questionnaire consisted of two main parts. A copy of the questionnaire is included in the appendix. The first part included questions about which of two injured individuals should be given preference if only one life could be saved. The only information given was their age and sex. The purpose of these questions was to see if people's stated preferences were consistent with human capital valuations. The second part of the questionnaire included questions about willingness to pay for special heart attack ambulances and other equipment and personnel that could get assistance to heart attack victims more quickly. For the first willingness-to-pay question, the number of lives expected to be saved out of a given population with each of two options was given and respondents were asked how much they would be willing to pay in taxes per year for these services to be supplied in their communities. Half of the questionnaires were worded "pay yourself" rather than "pay in taxes". Whether this caused any significant difference in responses was not discussed. Respondents were then asked how much they would advise their neighbor to pay for a given reduction in risk of heart attack fatality and how much they would pay for the same reduction in risk for themselves. The first level of risk described was a chance of 1 in 100 of a heart attack and odds of 2 to 3 of it being fatal. (This is close to the average annual risk of fatal attacks in the United States that was described in the first willingness-to-pay question in a somewhat different way.) Willingness-to-pay questions were asked with regard to services that, once a heart attack occurred, would reduce the risk of dying by half and by a quarter. The second level of risk considered was if the doctor had told your neighbor (or you) that his (or your) chance of having a heart attack was 5 times the normal level with the odds of it being fatal once it occurred still being 2 to 3. WTP questions were again elicited for special services that would reduce this risk of dying from a heart attack by a half or by a quarter.

The different levels of risk were illustrated for the respondents with bar graphs. This is probably a useful device for helping the respondents understand the levels of risk being evaluated.

Results

The responses to the 'who should be given preference' questions will not be emphasized here as they are not our focus. They did, however, indicate a consistency with the age pattern of human capital valuations except in the younger age ranges which were given preference over some of the older age groups. While the human capital approach would imply a general preference for saving men because they earn more, the survey found no preference for saving men versus women.

Some zero bids and refusals to bid on the valuation questions were encountered, but the reasons for them were not explored. They could have reflected true zero valuations, rejection of the supposition that the individual should pay for such services, or confusion about the meaning of the question. Probing for such underlying reasons would have been helpful in order to know how to treat them in the analysis.

Table 4.1 gives the mean bids and standard deviations of the responses for the three samples. The implied value per life saved for the community sample is also given. The community sample results are emphasized since potential sample biases introduce an unknown error into the results for the other two groups. As the questions became more personal from describing risks for the community to describing risks to your neighbor and to yourself, the implied willingness to pay per life saved increased, although the valuation differences between what respondents would advise their neighbor to pay to reduce his chance of a fatal heart attack and what respondents would pay to reduce their own chance of a fatal heart attack were not large. It is interesting that in each case, when the number of expected lives saved was cut in half the bids were not cut in half, implying a decreasing marginal value of reduced risk, even when the starting point was the same for both questions. Such a declining marginal value of additional units of a good is typically found with market goods and it is possible that decreases in risks are viewed the same way. Changing the order of such questions and making sure the respondents understand the net change in risk being valued could test if this result is a true reflection of preferences or not.

The calculated value per life saved is considerably smaller for the questions that hypothesized an elevated level of risk. Theoretically, it is expected that people who are at greater risk would be willing to pay more for a unit reduction in risk than would people at a lower risk. This is because people at greater risk have a shorter life expectancy and

Table 4.1
Acton: Mean Willingness to Pay for the Three Samples
(1972 dollars)

Willingness to Pay	Community (N = 32) ($)	Trade-Union Leaders (N = 14) ($)	Business Executives (N = 14) ($)	Value ($) Per Life Saved[b] (Community Sample)
WTP1	33	45	75	16,500
(20 lives) (1/100, 1/5; 0.002)[a]	(32)	(30)	(123)	-
WTP2	24	28	43	24,000
(10 lives) (1/100, 1/10; 0.001)	(28)	(27)	(63)	-
Advice to Neighbor on WTP				
WTP3	48	90	52	24,000
(1/100, 1/5 reduction; 0.002)	(61)	(68)	(37)	-
WTP4	38	47	34	38,000
(1/100, 1/10 reduction; 0.001)	(61)	(38)	(31)	-
WTP5	136	121	207	13,600
(1/20, 1/5 reduction; 0.01)	(376)	(147)	(253)	-
WTP6	86	70	150	17,200
(1/20, 1/10 reduction; 0.005)	(192)	(78)	(244)	-
One's Own WTP				
WTP7	56	61	58	28,000
(1/100, 1/5 reduction; 0.002)	(68)	(48)	(53)	-
WTP8	43	40	32	43,000
(1/100, 1/10 reduction; 0.001)	(63)	(29)	(32)	-
WTP9	74	84	223	7,400
(1/20, 1/5 reduction; 0.01)	(73)	(67)	(268)	-
WTP10	60	52	118	12,000
(1/20, 1/10 reduction; 0.005)	(71)	(44)	(130)	-

NOTE: Numbers in parentheses under the mean bids indicate standard deviations of the bids.

[a] Parenthetical statement reads 1/100 chance of a heart attack, 1/5 reduction in probability of death; 0.002 probability of the life being saved by the program.

[b] Calculated from the reported community means divided by the associated probability of a life being saved.

Source: Acton (1973) p. 87.

therefore would be more willing to trade future income for a current reduction in risk since they have less of a chance of living to enjoy that future income. The survey results seem to contradict this theoretical conclusion, but upon closer examination they do not. This is illustrated in Figure 4.2. Two possible WTP per life saved curves are given with a higher one shown for the higher initial risk level. They are drawn such that the value of each additional life saved decreases given the initial level of risk. On the horizontal axis is the hypothesized number of lives saved in each of the scenarios. The survey results provide observations for points A, B, C, and D. The dashed lines show that these observations could be consistent with a higher WTP per life saved when the initial risk level is higher. However, this hypothesis is neither confirmed nor contradicted because the observations do not overlap. All that they suggest is that additional lives saved are valued less for the same initial risk level.

Overall, the implied values per life saved are quite low. According to the author, they are reasonably close to values that would result from the human capital approach. The values for a life saved implied by the results of this survey, when applied to risks at typical U.S. heart attack levels, were $28,000 and $43,000 (1972 dollars).

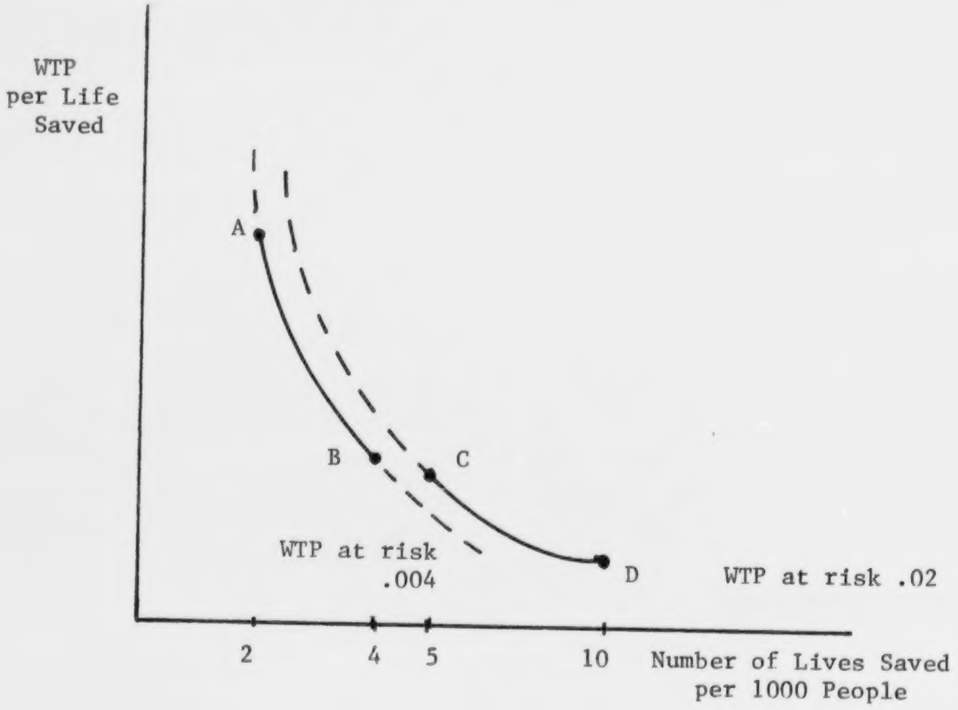
In order to examine the differences between bids, a few regressions were estimated with bids as a function of income, wealth, medical expenditures, sex, education, whether or not the respondent cited a history of heart disease or poor health, whether or not the respondent cited heart disease as an important problem, and a few other variables. The regressions explained about one-third of the variation in bids. The income and wealth variables were, for the most part, insignificant and of unstable sign. Two of the most consistently significant variables were whether the respondent thought heart disease was an important health problem and whether the respondent had a history of heart disease or ill health. Surprisingly, the latter variable had a negative sign. The explanation for this offered by the author was that there were very few respondents for whom this variable had a value of one and the result was therefore a statistical anomaly. Another possibility is that the expected quality and remaining length of life for a heart attack victim may be low, reducing his willingness to pay to reduce the risk of death.

Comments.

As a first effort of this kind, the questionnaire design and survey implementation were creatively and carefully done. However, the presentation of risks in two stages—first of

Figure 4.2

WTP per Life Saved



having a heart attack and second of dying once the heart attack occurred--may have been a bit confusing to survey respondents, particularly given the large number of different alternatives respondents were to consider. In the third sample, the questions included the total reduction in risk of death that the program would provide. In other words, when the chance of a heart attack is 1 out of 100 and the odds of it being fatal are 2 to 3 and the program cuts these odds in half, then the chances are 2 out of 1,000 that a heart attack will occur but a fatality will be prevented by the program. This last clarification and summing up of total benefits of the program would have been good to include for all the samples. The switching back and forth from the chances (i.e., 1 out 100) to the odds (i.e., 2 to 3) was probably more confusing than helpful.

Another possible problem may have been that respondents were weighing for themselves what their risks of heart attack were, rather than taking the suggestion of the question. The use of "your doctor has told you that" as a device for getting respondents to consider risks of heart attacks other than what they perceived to be their true risks was not used in the first two willingness-to-pay questions. It is hard to know whether respondents were thinking of the average risk of death due to heart attack as their own or were making their own judgements about what their actual risks were. It is probably common knowlege that every one does not face the same risk. According to the author, very few respondents cited a history of heart disease or ill health, which lends some support to this as an explanation of the low bids.

It may also be that the order of the questions influenced the pattern of the responses. In each case questions went from the community to the individual and from lower risks to higher risks. Asking these questions individually (i.e., asking each respondent only part of the questionnaire) or in a different order might have resulted in different responses. This possibility needs to be tested in future efforts.

4.1.2 Jones-Lee (1976)

For this study, the author designed a questionnaire asking respondents to estimate the dollar compensation required for them to accept additional risks of death or the amount that they would pay for reductions in risks of death, using the examples of airline safety and environmental hazards. His purpose was not so much to provide comprehensive estimation of the value of safety, but to illustrate a possible procedure and test its credibility in application.

Survey Instrument and Procedure

In early 1975, a sample of ninety people, who were academic and research workers and a few public sector employees, were sent the questionnaire (a copy is included in the Appendix). Responses were received from thirty-one individuals.

Two topics were addressed in the questionnaire: the value of changes in probability of death and the value of changes in life expectancy. In order to ground these questions in realistic decisions that individuals make, these were couched in terms of choices between airlines with different accident rates and between residential locations with different levels of unhealthful environmental pollution. Respondents were told that airline A has a fare of £100 and a safety record of 2 fatal crashes per 500,000 flights. This is close to the actual risks of airline accident fatalities. They were then asked what fare would just induce them to take Airline B given different safety records for B, some better and some worse than Airline A. It was expected that the fare would be more than £100 for safety records better than A and less than £100 for safety records worse than A. They were instructed to put an X if there were no fare that would induce them to switch from Airline A to Airline B.

The second group of questions asked respondents to consider that they were moving and had to choose between Area A, where environmental pollution was such that average life expectancy was normal and Area B, where life expectancy was longer or shorter by specific amounts. Respondents were asked how much the housing premium or discount would have to be to just induce them to move to Area B.

Results.

The author reports the answers of all the respondents. For the most part, they are reasonable within the context of the questions. Two respondents were, however, apparently confused about the first question, because they said it would take a lower fare on Airline B to get them to accept less risk. Two-thirds of the respondents indicated that there would be no fare that would induce them to accept one or more of the higher levels of risk. It might have been useful to ask them how else they would have taken the trip or what they would have to be paid (i.e., what negative fare) in order to accept these risks, although this would introduce less realism. About one-third of the respondents indicated that they would not pay any additional fare for a reduction in risks to 1 out of 500,000 or to no risks of fatal accidents. The author suggests that maybe these differences in risks are so small that they are considered equivalent. It would be interesting to explore whether this was the actual reasoning behind these responses or whether there was some sort of objection to the idea of having to pay more.

The author calculated the implied values per life saved by each of the respondents excluding the two who indicated negative values of life and those who gave no fare other than 100 or said that there was no fare that would induce them to take Airline B (these might also indicate a rejection of the idea of trading off fares versus safety). Values of life were therefore calculated for twenty-four respondents, using the response for a risk increment as close as possible to the overall risk of death faced by the respondent, given his age. The change in airline safety considered therefore varied from respondent to respondent. These value of life estimates ranged from £.08 million to £12.5 million with a mean of about £3 million. This amounts to about $6.7 million in 1975 U.S. dollars. The changes in risk considered range from a decrease of 4×10^{-6} to increases of 3.6×10^{-5}, but most of the value of life estimates are based on reductions in risk levels because a high fraction of the respondents said there was no fare that would induce them to accept the higher risks. These estimates therefore represent lower bound estimates.

The responses to the question concerning willingness to pay for changes in life expectancy indicate that the respondents require more compensation for decreases in life expectancy than they would be willing to pay for a comparable increase. Willingness to pay for 5 years additional life expectancy ranged from £200 to £20,000 while compensation required to accept a 5-year reduction in life expectancy ranged from £800 to £15,000 with several respondents saying there was no amount for which they would accept this decrease in life expectancy. Sample averages were not calculated.

Comments

The scenarios used in the survey were carefully defined, although the questions require reading through a few times before the meanings are clear. Unfamiliarity with the concepts being addressed might make it very difficult for a respondent in self administering the questionnaire. For example, the concept of "just induce" and "probability density function for time of death" could cause some difficulty for a more representative sample. The question is trying to elicit the change in fare or difference in housing prices that would cause the respondent to be indifferent between the two alternatives. It would be interesting to know if the respondents understood this.

Most responses confirmed the hypothesis that bigger increases in risk require more compensation, but the evidence is mixed concerning the change in the value of life as the level of risk changed. Some responses reflected a linear marginal valuation—the same increment in risk is valued the same no matter what the initial level of risk is. Others indicate increasing marginal valuations as risks increase—additional increments of risk require more and more compensation as total risks increase. This implies that values of life will increase as risks increase, but some of the responses indicated just the opposite. The limited range of risks considered and the small number of responses makes this difficult to explore more extensively.

4.1.3 Murphy (1979)

This study was conducted in the context of analyzing the risk and discomfort of treating sore throats immediately versus the risk and discomfort of waiting until culture results are available. Small risks of potentially fatal complications from the medication or from delaying treatment are encountered either way. The hypothesis was made that people value their lives in terms of the future pleasure they expect from the various activities which they undertake. Risks of injury or death can therefore be valued in terms of the risk of this lost future pleasure. The value of changes in risks is calculated from the tradeoff between risks of lost pleasure and the tradeoff between pleasure and income.

Survey Instrument and Procedure.

Forty volunteers, patients and staff at Ingham Medican Center, Lansing, Michigan, were asked a series of questions. First, they estimated the average number of hours per week that they spent in any given activity. These included sleeping, personal care, eating, commuting, working, evening leisure, weekend leisure, vacation, work at home, hospitalized, and sitting and thinking. They were then asked to rate how much they enjoyed these activities on a five point scale—very pleasant, mostly pleasant, equally pleasant and unpleasant, mostly unpleasant and very unpleasant. These ratings were used to calculate pleasant hour equivalents (PHE) for each of the activities. Those of the volunteers who were employed (twenty six of them) were also asked about what compensation, in terms of their wage rate, they would require to work overtime for three hours on an evening or weekend.

Results

Table 4.2 shows the results of the questions concerning how time during the week is spent and gives the average PHE per hour for each activity when these are rated from 2 to -2 with very pleasant being 2 and very unpleasant being -2. The average total PHE for each activity is then calculated. The sum of these gives the average total PHE for the week. Because the total reported hours did not add up to 168, the total PHE was increased proportionally to obtain an estimate of average weekly PHE per individual. This presumes that the hours not reported are distributed among activities in the same proportion as the total hours that were reported.

All but four of the employed respondents said that they would require an hourly compensation of 100 percent to 200 percent of their regular hourly pay in order to work three extra hours per week. The median value was 150 percent (the mean was 153 percent). This value was used to calculate the dollar value of a PHE. The average PHE for working was .77 and for leisure was 1.47, so working overtime means an average loss of .70 PHE per hour. If 1.5 times regular hourly pay is adequate compensation for this PHE loss, then a PHE is worth 2.14 times regular hourly pay.

The author goes on to calculate the dollar value of the total PHE in a week. With an average of 133 PHE per week, a week is valued at 185 times regulary hourly pay or approximately 7 times the individual's take home salary. For an annual take home pay of $10,000 and 30 years of expected remaining life, the author suggests that the life is valued at approximately $2 million. He points out that this is only applicable for small changes in risks to the individual. This estimate should probably have been discounted since promise of a PHE ten years from now is probably not as valuable as a PHE this year. The calculation would then be seven times the present value of expected future earnings.

Table 4.2

Murphy: Average Pleasant Hour Equivalents Spent Per Week

	Total hours/ 40 volunteers	Average PHE*/hr	Average PHE*/volunteer
Sleeping	50.9	0.55	27.995
Personal care	7.7	0.60	4.62
Eating	9.6	1.18	11.328
Commuting	2.6	0.35	0.91
Working	29.4	0.77	22.638
Evening leisure	19.2	1.44	27.648
Weekend leisure	6.1	1.49	9.089
Vacation	3.4	1.53	5.202
Work at home	11.5	0.45	5.175
Hospitalized	3.5	0.05	0.175
Sitting and thinking	4.8	0.62	2.976
Other	6.1	0.78	4.758
Total	154.8	--	122.514

* PHE = pleasant hour equivalent

Corrected for 168 hr per week: $122.514 \times \frac{168}{155} = 132.79$. Therefore, the average volunteer spent 133 PHE's each week.

Source: Murphy (1979) p. 206.

Comments

The numerical estimates of the value of life that resulted from this study are highly questionable due to the major assumptions made in their derivation—the quantification of PHE's and the dollar tradeoff based on the first three hours of leisure given up. The numerical scale used for quantifying PHE was entirely arbitrary. Although a very pleasant hour is no doubt preferred to a merely pleasant hour, there is nothing to say that it is exactly twice as preferred. Thus, the sum of these numerical PHE's is difficult to interpret. It is hard to believe that it is a reasonable reflection of the enjoyment of life. The tradeoff between income and PHE's was based on what respondents say would compensate them for three hours of overtime per week. It would be expected that more hours of overtime per week would require even more compensation. Every hour of leisure is probably not equivalent. The first three hours given up are likely to be taken from leisure activities at the lower end of the pleasure scale. It is not, therefore, appropriate to use the dollar compensation required to give up the first three hours of leisure as the dollar value of the average PHE difference between work hours and leisure hours. For additional leisure hours given up, it can be expected that more and more compensation would be required. The responses were probably also influenced by the overtime wage available to the respondent.

The procedure is, however, an interesting contribution. It allows the respondent to answer questions about how much he enjoys the typical activities he undertakes during a week without having to directly put dollar values on life. It also suggests a way to incorporate the quality of life. Risks of disability or illnesses can be treated as a risk of reduction in the individual's PHE's, and risk of death as the risk of the total loss of PHE's.

A problem with the survey procedure was the lack of a statistically correct sample of respondents. The researcher cannot place much confidence in estimates that are obtained from a nonrandom sample. Such a sample is potentially subject to an unknown degree of bias in terms of the characteristics of the people queried. Such a sample can, however, provide a useful test of the survey instrument and the valuation procedure.

Improvements in this procedure would include a more detailed rating of the pleasure derived from various activities. The problem of whether these can be meaningfully summed across individuals would remain. The income and pleasure tradeoff would have to be quantified differently so as to avoid or account for the problem of marginal versus average values. As it stands, this approach used to translate PHE's into dollars is also not applicable for those who are not employed. Changes in PHE's over a person's lifetime should also be examined. The current procedure presumes that using up PHE's has no effect on the value of those that remain. As a person's life expectancy changes, so may his valuation of PHE's. An appropriate adaptation of this approach might focus on risks of morbidity rather than risks of mortality.

4.1.4 Frankel (1979)

This study entailed a survey to enquire into peoples' responses to questions about the monetary value of changes in their safety or longevity and what these responses reflect about their attitudes toward safety and longevity.

Survey Instrument and Procedure.

The questionnaire was administered to three groups--faculty members in the Business School (60 percent of respondents), middle level executives in an executive M.B.A. program (28 percent of respondents), and faculty members in the College of Law (12 percent of respondents)—all at the University of Illinois at Champaign-Urbana. A total of 169 usable responses were obtained for a response rate of 69 percent. This kind of sample is not necessarily representative for a wider group of individuals so that the resulting estimates may be of limited value for policy purposes, but they do offer information about the ability and willingness of individuals to respond to these kinds of valuation questions.

Questions included how much the respondent would pay to assure his uninjured survival of an airline flight given current average fatality rates (a 1.5 in 1,000,000 chance that a flight will result in a fatal crash) and a hypothetical higher risk of 1 out of 1,000. A second area addressed was attitudes about and willingness to pay for changes in remaining expected years of life and for guaranteed changes in life span.

Results.

Respondents said that they would be willing to pay a median amount of $4.45 to prevent a 1.5×10^{-6} chance of an airline crash fatality on one trip. This implies a value per life saved of $2.97 million (1979 dollars). Responses varied widely, however, with 23 percent saying they would pay nothing and 12 percent saying they would pay $100 or more. The author suggests that these latter responses are implausibly large and may reflect an unrealistic anxiety about flying. When these values are excluded, the median falls to about $2.50, implying a value of life of about $1.67 million.

A second question asked how much respondents would pay to be sure that a 1 in 1,000 risk of an airline crash fatality would be reduced to zero. The median response was $50.37 with about 10 percent saying they would pay nothing and about 10 percent saying they would pay $1,000 or more. This response was not a proportional increase to the increase in risk reduction being evaluated and implies an average value of life of only $50,370. A proportional increase would have required proposed payments of 1,500 times the original ones.

The longevity questions began with asking the respondent to look at tables showing his life expectancy for his age group and then saying whether he thought he would live more years, the same number, or fewer years. Over 44 percent said they would live longer and only 13 percent said they would live fewer years. This might reflect the good health that the respondents also reported, but the author suggested that this might also reflect people's tendency to think it's not going to happen to them. This is an indication that people may not make judgments about taking risks the same way they make judgments about which car to buy. If such optimism is pervasive, then values of life implied by consumer and worker choices and even by stated valuations will be understated because individuals will always be judging their true risk of death to be less than it is.

The next group of questions were about changes in life expectancies. The results are summarized in Table 4.3. The author notes the large difference between the bid for an increased year of life expectancy and a guaranteed additional year (over what one would normally live) as an indication of strong risk aversion.

A final set of questions asked about compensations for reductions in life expectancy. The first hypothesized that an industrial accident which caused you no immediate injury

Table 4.3

Frankel: Valuations on Changes in Life Expectancy (1979 Dollars)

	median	% who would pay nothing
1 year increase in life expectancy	$5.33	44%
5 year increase in life expectancy	$500.	31%
1 year additional guaranteed	$500.	30%

Source: Frankel (1979)

has exposed you to hazardous substances such that your life expectancy has been reduced by one year. The respondent was then asked to estimate what he would consider fair and full compensation for this exposure. The median response was $30,000, although 25 percent of the respondents said $100,000 or more. The next question asked if the respondent would accept an amount equal to 10 percent above his answer to the previous question to voluntarily give up a year of remaining life expectancy. Eighty percent said no. The author suggests that this may reflect a distaste for regarding life as a marketable item. It might also reflect the difference in the initial utility level implied by the two questions, the first being lower since the loss had already occurred. This difference might also be related to a difference in reaction to an accidental injury versus an intentional injury or to death caused by hazardous substances versus an unspecified cause of death.

Compensation for an involuntary five year loss in life expectancy had a median value of $200,000, seven times more than for the one year loss. Projected linearly for the life expectancy of a 41 year old man (the mean of the sample), these two points implied a value of life of $1.35 million.

Comments

The questions posed to respondents in this survey were phrased to carefully communicate the change in risk or longevity being valued but no attempt was made to create a realistic market or payment mechanism by which such a transaction might occur. The air travel question, for example, suggested that respondents imagine purchasing a magic amulet (charm) that would guarantee for a single flight his uninjured survival in the event of a crash.

As an explanation of the low value of life implied by the responses to the second question, the author suggests the individual's responses were influenced by an income effect. A large loss in wealth may reduce the individual's willingness to pay for a reduction in risk. The low bids relative to the previous ones may also reflect the lack of realism of the question. Surely air travel would not be a viable alternative if the risks of death were 1 out of 1,000 for every flight. The payment people would actually be willing to make to prevent such a risk may be much more than anyone could imagine paying with respect to a single airline flight.

For most of the valuation questions, there was a high percentage of zero responses, as well as a fairly high percentage of very high responses compared to the median. The author speculates about various possible reasons for these extremes, but it would be interesting to probe the respondents themselves in future survey efforts. Very little is known about what these valuations are based upon.

4.1.5 Mulligan (1977)

The purpose of this study was to examine willingness to pay for reductions in risks of death and injury due to nuclear plant accidents and willingness to accept compensation for increases in such risks. Several hypotheses were tested. One was whether the respondent's income was correlated with whether he was willing to pay any positive amount to reduce risks of injury due to nuclear plant accidents. Another focus of the study was an attempt to consider future generations by asking a group of parents to bid for their children instead of for themselves.

Survey Instrument and Procedure

A random sample was drawn from the Parents and Teachers Association membership of three Lewiston, Pennsylvania, elementary schools and from the Lewiston Tax Assessor's housing directory.* Eighty-two usable responses were obtained. Thirty of these were from adults answering the questions for themselves, thirty-two were from parents answering the questions for their children and twenty were from parents answering for themselves as a control group to see if parents as a group would provide different results. (A copy of one version of the questionnaire is included in the Appendix). The response rate was not reported.

The questionnaire was introduced with a brief description of the kinds of fatal and nonfatal injuries that can result from nuclear plant accidents. Serious injury was described as any illness or injury resulting from a plant accident that would normally require hospitalization. Respondents were told to also consider long-term effects such as cancer, sterility, birth defects and shortening of life expectancy. It was explained that the respondent would be asked how much he would pay or accept in compensation in terms of his monthly fuel and electric bill in order to reduce risks of accidents or accept increased risks. Specific procedures for reducing risks were not given but respondents were told that these could include changes in the nuclear plant itself or changes to different energy systems. Half of the respondents were first asked the willingness-to-pay questions and half were first asked the willingness-to-accept-compensation questions.

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* This is not too far from Three Mile Island but the study was conducted before the accident occurred there. A post Three Mile Island follow-up is now being conducted by Stuart Mann at Pennsylvania State University.

The levels of risk described were purely hypothetical. No specific nuclear plant facility or location was referred to, although there are several that have the potential of affecting the survey area. The first change in risk of injury or death respondents were asked to evaluate was a decrease from 1 in 1,000 to 1 in 10,000. They were then asked how much additional they would value a change from 1 in 10,000 to 1 in 100,000 and so on to 1 in 10,000,000 to 1 in 100,000,000.

The author mentioned that the highly contested estimates of an accident probability by the former Atomic Energy Commission were 1 in 1,000,000,000. The risk presented in the scenarios was not risk of accident, but risk of injury which would be even lower because each individual faces a less than 100 percent chance of being injured or killed in any given accident. Nevertheless, the author suggested that the lower levels of risks used in the survey could be within the range of real world risk probabilities. The higher levels with which the questioning began were, however, probably outside the realm of realistic possibilities.

Results

A summary of the survey results is given in Table 4.4. Of the eighty-two responses, four people did not give a value estimate for any of the questions. For the willingness-to-pay questions, the mean bids did not decrease in proportion to the reduction in risk being valued. What is even more problematic is that the maximum bid did not fall, in all cases, as the risk reduction became smaller. At least one person must have bid more for a smaller reduction suggesting that he or they may not have understood the question. The number of people who bid zero, implying that the additional reduction in risk was of no importance, increased to over a third of the respondents by the time the smallest risk increment was reached.

Table 4.4

Mulligan: Survey Results

(1977 Dollars)

		WTP Questions		
Change in risk	Mean bid	Median bid	Maximum bid	Number who bid zero*
9×10^{-4}	$3.41	$1.50	$25	6
9×10^{-5}	$2.36	$1.40	$10	12
9×10^{-6}	$1.97	$1.20	$11	16
9×10^{-7}	$1.65	$.97	$18	25
9×10^{-8}	$1.53	$.86	$14	30
WTA Questions (were asked in opposite order)				
				Number who said they would not let risks rise
9×10^{-4}	$2.00	$.80	$9.00	75
9×10^{-5}	$15.71	$4.00	$90.00	75
9×10^{-6}	$8.75	$2.50	$30.00	74
9×10^{-7}	$8.18	$4.38	$30.00	71
9×10^{-8}	$17.94	$10.00	$90.00	66

* Total sample was 82.

Source: Mulligan (1977)

The responses to the willingness-to-accept-compensation questions indicated that for the same increase in risks (the questions started with the lowest and worked up to the highest risk levels) a very high percentage of the respondents said that they were unwilling to let the risks rise for any amount of compensation. Respondents were asked their reasons forthis refusal. Their explanations were things like life is sacred, the future, children and other people should be protected, and risks should be prevented.

The amount that people were willing to pay to reduce risks was found to be higher for respondents with higher incomes, although income was not correlated with whether or not the respondent was willing to pay something. Parents bid amounts for their children similar to what they bid for themselves.

Values per life saved cannot be derived from these survey results unless some assumptions are made about the presumed time frame over which the risks were to be incurred and about the fraction of injuries that would be fatal. No time frame was given for the change in risk that was presented to the respondent for valuation. Respondents were asked, for example, to value a reduction from a 1 in 1,000 chance of injury or death to a 1 in 10,000 chance of injury or death, but were not told whether these were annual probabilities or were the probabilities of such an injury in a person's lifetime. Respondents gave estimates of monthly willingness to pay for this reduction in risk, but it is not clear whether twelve of these payments are purchasing this reduction each year (i.e., 9 out of 10,000 fewer will be injured each year) or whether a lifetime of these payments is purchasing this reduction in risk over the lifetime (i.e., the respondent could expect that there will be a 9 out of 10,000 fewer injuries in his lifetime).

Table 4.5 gives some illustrations of the effect of two possible time frame assumptions on the estimated values per life assuming that all the injuries are fatal. If a significant proportion were not fatal, then the value per life would be some fraction of the amounts suggested for each time frame assumption. Clearly, the time frame assumption has a large effect on the implied values of life. Even more troublesome is the wide range of values per life saved for any given time frame assumption. For each willingness-to-pay question, the risk increment decreased by a factor of ten, but mean bids did not fall this rapidly. As with the Acton survey, the questions posed changes in both the initial level of risk and the change in the number of injuries. This makes it impossible to tell whether it is the change in the risk increment or the change in the initial level of risk that is causing the nonlinearities.

Table 4.5

Illustrative Value of Life Calculations from Mulligan Survey Assuming all Injuries are Fatal

Risk increment	Value/life if risks are annual[1] (thousands)	Present Value of payment over remaining lifetime[2]	Value/life if risks are over remaining lifetime (thousands)[3]
9×10^{-4}	$ 45	$397	$ 441
9×10^{-5}	$ 315	$275	$ 3,052
9×10^{-6}	$ 2,627	$229	$ 25,479
9×10^{-7}	$ 22,000	$192	$ 213,400
9×10^{-8}	$ 204,000	$178	$ 1,978,800

[1] These figures were calculated by multiplying the mean monthly bid by 12 and dividing by the risk increment.

[2] These figures are approximations of the present value of the mean monthly payments paid over 40 years of remaining life and using a 10% discount rate.

[3] These figures are calculated by dividing the present value of payments over remaining life by the risk increment.

Comments

This study was more carefully done than many of the others because the questionnaire was pretested and refusal bids were probed. However, several serious problems remained with the survey instrument. As discussed above, no time frame was given on the risk levels so the amount of risk being evaluated is actually unknown. Another problem was that the bidding questions started with asking the respondents if they would pay $5. Previous studies have found that this kind of leading question can bias the responses (See Rowe and Chestnut, 1982).

The presentation of the numerical risk levels were not tied to real world risk levels associated with nuclear energy production. Respondents were told that these were hypothetical figures and were not given any information about what kind of probabilities of risks are actually predicted with respect to nuclear facilities. This makes it difficult to know whether respondents were valuing the risk changes described or whether they were influenced by some notion of what they thought the risks of nuclear plant accidents might actually be.

The refusals to respond to the compensation questions are troublesome because clearly the respondents did not catch on to the spirit of the question as it was intended. Economists hypothesize that people are willing to make tradeoffs between risks and income and expect these tradeoffs to go in both directions. The respondents seemed to accept the idea that they might have to pay higher utility bills in order to have risks of nuclear plant accident injuries reduced, but were not willing to think about that tradeoff going in the other direction. This seemed to be because the risks would be imposed on others too and maybe underneath some of the explanations was a belief that the risks should be minimized--letting them rise means we will tolerate risks that we are capable of preventing. Maybe this kind of problem can be avoided with a more careful introduction that gets people to think about such tradeoffs in a more pragmatic way. Respondents might be willing to accept the idea if it were pointed out that we frequently tolerate certain levels of risks that could be prevented (such as driving an automobile) because the prevention means costs we are not willing to incur. Income constraints and property rights issues (what level of safety does one have a "right" to?) can also influence willingness-to-pay bids versus willingness-to-accept-compensation bids. These issues are unresolved and need to be more fully examined with respect to valuations of safety.

4.2 SUMMARY OF CONTINGENT MARKET STUDIES

None of the value of life estimates that have come out of these contingent market studies is really sound enough for use in policy decisions. None of these studies is without serious shortcomings in its formulation or implementation and the range of results across studies and within studies is quite large, as is illustrated in Table 4.6. The promise that these studies offer is that it may be possible to formulate survey instruments that can elicit reasonable risk valuations relevant to specific policy questions. Certain problems that have arisen must, however, be addressed in order to develop more defensible survey instruments. A careful review of the now extensive literature concerning contingent market techniques could significantly improve upon the applications that have been described here. Payment mechanisms, scenario development, sample selection, questionnaire pretesting, bidding procedures, and tests for biases all need close attention. Many of these problems point to the need to conduct interviews in person in future survey efforts of this type.

All of these studies had some problems in the presentation of the scenarios, the hypothetical market and the change in risk being valued. Acton's questionnaire was probably the best such presentation. The suggested actions for reducing risks of heart attack fatalities were well defined and realistic; however, the payment vehicle by which these programs would be supported was left rather vague and although all the necessary information about the change in risk to be valued was given, it was rather confusing. The Jones-Lee questions were fairly well presented in terms of the levels of risk to be evaluated and the market mechanism, but the scenarios in which these choices might have to be made were not well developed and the presentation presumed a well educated audience. The Frankel and Mulligan surveys were both rather weak in the realism and detail of the scenarios. The Mulligan survey was especially flawed in terms of the description of the risks to be valued. Future survey efforts need to take pains to develop realistic and detailed scenarios and to present the tradeoff the individual is being asked to consider in a straightforward and simple manner. A realistic context in which the individual might have to make such a tradeoff should be carefully described.

Table 4.6

Summary of Value of Life Estimates from Contingent Market Studies[1]

Study (Year Dollars)	Initial level of risk	Increment of risk	Average value per life (thousands)	May 1982 $ (thousands)	Nature of risk examined
Acton	$4x10^{-3}$	$2x10^{-3}$	\$28	\$64	heart attack fatalities
(1972)	$4x10^{-3}$	10^{-3}	\$43	\$98	
		$2x10^{-2}$	10^{-2}	\$7.4	\$17
		$2x10^{-2}$	$5x10^{-3}$	\$12	\$27
Jones-Lee (1975)	0 to $4x10^{-5}$	$2x10^{-6}$ to $2x10^{-5}$	\$178 to \$27,750 (mean = \$6,700)	\$317 to \$49,423 (mean = \$5,343)	airline accident fatalities
Murphy[2] (1978)	--	--	\$2,000	\$2,937	—
Frankel	$1.5x10^{-6}$	$1.5x10^{-6}$	\$2,970	\$3,922	airline accident
(1979)	10^{-4}	10^{-4}	\$50	\$60	fatalities
Mulligan[3]	10^{-4}	$9x10^{-4}$	\$45	\$71	nuclear plant
(1977)	10^{-5}	$9x10^{-5}$	\$315	\$498	accident injuries
		10^{-6}	$9x10^{-6}$	\$2,627	\$4,151
		10^{-7}	$9x10^{-7}$	\$22,000	\$34,760
		10^{-8}	$9x10^{-8}$	\$204,000	\$322,320

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[1] This table is for summary and comparison purposes. Before using the estimates, the reader should understand the assumptions and procedures by which they were obtained.

[2] This estimate was not linked to a specific risk or risk increment although the author states that it is relevant only for small changes in risks.

[3] These are based on the assumption that the survey question referred to annual risks and that all injuries are fatal.

Only in the Mulligan study were respondents questioned about their unwillingness to answer valuation questions. Mulligan found that over 80 percent of the respondents said they were unwilling to accept any compensation to allow risks of nuclear plant accident injuries to rise. Many of the explanations offerred for this refusal reflected an aversion to the idea of being compensated for allowing increased risks that would also affect other people. This difficulty suggests that questions about tradeoffs concerning risks to the public should be phrased in terms of willingness to pay for reductions in risks as this is likely to be a more acceptable concept. This also indicates that respondents were having trouble thinking about the risks to themselves alone as they were directed to do by the introduction to the questionnaire. If respondents are not distinguishing how much they themselves are affected by the risks from how much friends, family and fellow human beings are also affected, this could be influencing willingness-to-pay estimates as well. This might be mitigated by careful presentation of the question, and by describing a payment mechanism whereby everyone pays equally.*

Other kinds of problem bids also need to be explored. Frankel found a rather high percentage of zero bids and very high bids relative to the means. These could be true valuations indicating a great deal of variation across people's preferences or they may indicate some difficulty with the question. Probing people's reasons for such bids would be helpful in deciding how to handle them in the analysis. Zero bids that were given because the respondent felt he should not have to pay for safety, for example, should probably not be used in the calculation of the sample means. Acton and Jones-Lee also found some inconsistent or illogical bids over different increments of risk. These might indicate confusion about the questions that could be cleared up during the interview process.

It is not expected that willingness to pay per life saved will be constant across people or across differences in the level and type of risk. The results of these studies provide some indication of the nature of these nonlinearities, but several questions remain. The Mulligan study found that higher incomes were associated with higher willingness to pay for reduced risks. The Acton study, however, found that income and wealth were not significant influences on the bids offered.

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* For policy purposes we might be interested in willingness to pay to protect society as a whole as well as to protect oneself. In either case the question needs to be carefully defined so that the responses can be correctly interpreted.

If safety is similar to a typical market good, then additional units will provide smaller and smaller increases in utility. This means that for a given starting point, it can be expected that value per life saved will fall as the number of lives saved increases. This was confirmed in the Acton study where respondents were asked their willingness to pay for a reduction from .004 to .002 and then from .004 to .003. The second mean bid was more than half of the first indicating that the first .001 reduction was valued more than the second .001 reduction.

Another expectation regarding nonlinearities in risk valuations is that at higher risk levels, people will be willing to pay more for an incremental risk reduction than they would be willing to pay if they were at a lower level of risk. This was illustrated in Figure 4.2. People at higher risk levels have less probability of being able to enjoy future income and wealth and are therefore expected to be willing to part with more money for the decrease in risk than would a person at a lower risk level, even though the change in risk is the same for both individuals. The contingent market studies have not provided any useful evidence on this question because in each case where higher risk levels were hypothesized, the increment of risk being evaluated was also changed. For example, in the Acton survey, respondents were first asked to consider a reduction in risk of a fatal heart attack from .004 to .002 and later a decrease from .02 to .01. Respondents raised their bids, but not in proportion to the increase in the risk increment being considered—.01 as opposed to .002. Problems may have also resulted because the higher initial risk levels suggested in these surveys were often outside the range that most of the respondents would consider realistic for the topic being discussed. This question could be more carefully considered in future survey efforts by keeping increments constant and changing the initial risk levels, and by using realistic ranges of risks.

The work of Tversky and Kahneman (1981) may shed some light on some of the apparent inconsistencies observed in the survey responses and on the importance of how the questions are phrased. They have developed the proposition that expected utility theory (individuals make choices that maximize expected utility) does not adequately predict peoples' preferences with respect to risk taking and that their alternative "prospect theory" is a better predictor of peoples' choices in the face of risks. They have found several systematic patterns: (1) people value risk taking differently if it is presented as a potential loss or a potential gain, (2) breaking down the probabilities into steps can result in different valuations even though the net result is the same, and (3) marginal losses or gains are less important as they become a smaller fraction of the total loss or gain being considered.

The first point is consistent with the Jones-Lee results that compensation required to accept a higher risk was more than the willingness to pay to obtain a comparable decrease in risk. The third point is consistent with the Acton results showing a decreasing marginal value of additional lives saved when starting from the same initial risk level. There is no such clear illustration of the second point, but it should be noted that Acton's results, which imply low values per life compared to most of the other results, are based on questions that present the risks of heart attack deaths as a two step probability. It is not clear whether Tversky and Kahneman's results refute the validity of expected utility theory or simply demonstrate systematic difficulties people have in interpreting probabilities, but they clearly demonstrate that how the question is phrased and presented can have a significant influence on the responses obtained.

The Murphy study was included because it is an example of an indirect valuation approach using a survey effort. In this case, respondents were asked to make judgements about the value of how they spend their time during a typical week but not directly in dollar terms. The tradeoff between pleasure and income was derived from a second question. Although there were problems with several assumptions made along the way in this study, the idea of indirect valuations is appealing when things are being considered that people do not usually think of as being purchased or traded. It may be easier for people to think in terms of, for example, time they are willing to spend to save lives than money. The problem with any approach of this nature is that the eventual conversion to dollars that must be made for benefit-cost analysis is seldom straightforward.

5.0 OTHER VALUE OF LIFE AND SAFETY ESTIMATION ISSUES

Chapters 2 through 4 have surveyed the available empirical estimates of the willingness to pay for changes in risk levels. This section will discuss some considerations that are relevant for estimating the willingness to pay for changes in risks, but that have largely been outside the scope of the currently available studies.

5.1 PROPERTIES OF AN INDIVIDUAL'S WILLINGNESS TO PAY FOR CHANGES IN MORTALITY

The hedonic wage-risk studies reviewed in Chapter 2 do not provide information on the properties of an individual's willingness to pay function for changes in risk. Instead, they map out a set of market clearing wage-risk combinations. Contingent valuation studies can be used to derive estimates of an individual's demand curve for safety, but the poor quality of existing studies limits their usefulness. A number of researchers (Weinstein, et al., 1980; and Thaler and Gould, 1982) have used decision theoretic approaches to explore the likely properties of individual willingness to pay curves. The principal conclusion to be drawn from these studies is that there is no unique value per life saved. This conclusion rests on two findings:

1) The willingness to pay for a reduction in the risk of mortality depends on the amount of the reduction and the initial probability of death.

2) The willingness to pay also depends on whether the decision is ex ante (e.g., medical insurance or preventive medicine) or ex post (e.g., after-the-fact intensive medical care).

This can be shown by using a conventional utility model where the individual chooses among lotteries containing life and death events with specified probabilities and assets. The model investigates opportunities for the individual to "buy a reduction in mortality" by trading assets for reduced probabilities for the "event" of death. Similarly, individuals have the opportunity to trade higher mortality risks for increased compensation. The buying and selling prices for mortality risks are determined by calculating the value of assets required to make the individual indifferent between two lotteries having different probabilities of life and death. Following the approach used by Weinstein et al. (1980), two behavioral assumptions are required to generate these results:

1) "life at a given assets position is preferred to death at the same assets position (plus net life insurance benefits and annuities);" and,

2) in simplified terms, "individuals prefer to receive increments to assets while alive rather than dead."

It is theoretically true that individuals with optimal amounts of annuities and insurance would be indifferent between incremental increases in assets while alive and increases in their legacy. However, Weinstein et al. feel that most people prefer to receive incremental assets while alive. They offer no rationale for this supposition other than a nonspecific reference to market imperfections. Still, this behavioral assumption has intuitive appeal. An argument that could be made in support of this second assumption is that one purpose of any legacy is to provide heirs with a target level of financial support in the event of a death (e.g., to pay off a home or business). Once this target financial security is established, additions to the legacy have a diminished value. Although this form of behavior does not meet all the criteria of rational man in conventional economic theory, given the complicated optimization problem, it may represent a reasonable compromise.

Using the mathematical expectation to generate a preference ranking of different lotteries, Weinstein et al. express the individual's utility function as:

$$U(d_L, z) = d_L U_L(z) + (1 - d_L) U_D(z).$$

If the individual survives the period, then d_L equals 1. If not, then d_L equals zero. The utility if the person survives is then $U_L(z)$, where z represents the individual's asset value. The utility if the individual dies is $U_D(z)$. In this representation, $U_L(z)$ and

U_D (z) are the asset utility functions for the uncertain events of life or death. Letting p be the probability of mortality, then expected utility can be expressed as:

$$E\,U(d_L, z) = (1 - p)\,U_L(z) + p\,U_D(z).$$

Given this model, Weinstein et al. prove two theorems. The first theorem addresses the question of how the value of a reduction in the probability of death from .4 to .3 compares to a reduction from .2 to .1. The reductions in risk are equal, but the initial base level of risk varies. Basically, the theorem states that the value of a reduction in mortality is greater, the greater the base probability of mortality. The reason for this result is that marginal assets are valued more highly in life than in death. This results in the individual being willing to pay more for reductions in risk at higher base risk levels since it is more likely that the payment will come out of the legacy rather than lifetime assets. This result is obviously dependent on the second behavioral assumption. If the second behavioral assumption does not hold and individuals are indifferent between increases in assets while alive or in their legacy, then the amount an individual would be willing to pay to reduce mortality probabilities would be independent of the base risk level.

The implication of this first theorem is that the cost effectiveness of programs to reduce mortality risks cannot be evaluated solely by dividing the cost of the program by the number of lives saved. Instead, the value of the reductions in risks will depend upon the specific individuals whose risks have been reduced and their base risk level. This first theorem implies that it may be desirable to devote more effort to reducing risks for those with high base risk levels.

The second theorem derived by Weinstein et al. states that the value of a reduction in risk depends upon whether the reduction in risk is evaluated ex ante to a particular health event that increases an individual's risk or ex post to the event. Further, there is a difference in the way the theorem operates for selling prices (i.e., willingness to accept compensation for increased risks) and buying prices (i.e., willingness to pay to reduce risks). In the case of the selling price, the calculated value of a statistical life will be higher when evaluated ex post than ex ante to a particular event as long as the individual is risk neutral or risk averse. With respect to the buying price, the same will be true if the individual is risk neutral, but for risk averse individuals the results are ambiguous.

For example, this second theorem says that the sum across 100 identical people of the compensation required to accept a given increase in the chance of contracting a life threatening illness that equals a statistical life (e.g., an increase in mortality risks from .01 to .02) will be less than the compensation required by the specific individuals who contract the illness. A more specific example can be given in the context of kidney dialysis. Each year approximately one out of 30,000 people suffers kidney failure and becomes a candidate for dialysis. Without dialysis, the individual will certainly die, with dialysis the individual is likely to live. The theorem states that if each one of these 30,000 individuals were asked what compensation he or she would be willing to accept ex ante to having kidney failure to forego the availability of a dialysis machine, the sum of these estimates over the 30,000 people, would be less than the compensation required by the one individual to forego having access to the dialysis machine after having had kidney failure. This difference in the selling price per expected life saved between ex ante and ex post evaluations holds whenever the individual is risk averse or risk neutral with respect to assets. Thus, in terms of the selling prices, the value of a statistical life is greater ex post than ex ante. For buying prices (i.e., the willingness to pay for reductions in risk), the result is the same for risk neutral individuals but ambiguous for risk averse individuals. As a result, empirical assessments of the magnitudes of the buying price are needed to make this ex ante - ex post comparison.

The policy relevance of this second theorem is that there may be an important choice between conducting empirical studies of the value of statistical lives from populations that are ex ante or ex post with reference to a particular health effect. Weinstein et al. state that the fact that "ex post willingness to pay tends to exceed the ex ante willingness to pay, at least in terms of selling prices, seems to support our societal tendency to invest much more heavily in health care for the sick patient than in preventive health measures." Further, they say that as the collective public pays a greater share of societal health costs, it becomes more compelling to view the appropriateness of these expenditures from an ex ante perspective.

5.2 THE CHOICE BETWEEN EX ANTE OR EX POST RISK VALUATIONS IN POLICY ASSESSMENT

Since ex ante and ex post willingness to pay estimates will often differ, there is a question as to which value is the most appropriate for policy assessment. Broome (1978) argues that, of these two, the ex post valuation is the correct one. An ex post valuation is made at the time the project is implemented and when all the details of its effects are known, including who will be hurt. Since ex post decisions are based on more information, Broome contends that they should be preferred. Most researchers, however, have argued in favor of using ex ante valuations (see Thaler, 1982; Thaler and Gould, 1982; and Mishan, 1982). Thaler (1982) makes the following arguments in favor of ex ante valuations:

1) Few projects are instantaneous. Decisions on whether to implement a risk reducing project may have to be made before the affected individuals are identified.

2) The additional information available in an ex post valuation is purely distributional--who will lose rather than how much. When choosing in the ex ante position this information is ignored by intent and its knowledge cannot improve the decision.

3) The choices made in the ex ante valuation are egalitarian. All individuals know the forthcoming distributions.

4) The ex ante "willingness to pay of individuals with low survival probabilities should be discounted, because their willingness to pay is based in part on their low survival opportunities. Since they are likely to die, the dollars they are offering are in some sense worth less to them." It is only their inability to trade risks with individuals in the low risk groups that allow them to outbid those groups.

5) In the final state, ex ante choices will save more lives and conserve more wealth. To the extent that these are the variables in the decision models, it is hard to fault ex ante choices.

Although there is not a clear consensus in the literature, the arguments for the use of ex ante, unidentified risk valuations in policy evaluation are persuasive. This has particularly important implications for any future contingent valuation studies since the hypothetical markets can be designed to value either ex ante or ex post risks. Given the arguments, the ex ante valuation seems superior for policy assessment.

5.3 THE VALUATION OF DIFFERENT RISK TYPES

Policy scientists have observed that individuals appear to place different values on different types of risk. For example, individuals seem to be more averse to accepting risks that are felt to be involuntary, i.e., risks imposed on individuals by society. The classification of risks as voluntary or involuntary is only one factor that has been used to characterize different types of risk. Litai (1980) presents twenty-six different risk characteristics that have been used to classify risk types (see Table 5-1).* The basic policy issue raised by this literature is whether people's willingness to pay for reductions in risk varies across risk types. A related question is whether societal decisions should reflect these different valuations, even if individuals do appear to value different risk types differently.

Much of the recent literature has been concerned with risk conversion factors (RCF's). W. D. Rowe (1977) presents the most detailed discussion of this concept. The basic premise of the approach is that actual behavior is useful for revealing existing social preferences and values for different risk types. The underlying assumption is that, over time and through a trial and error process, a rough equilibrium state between risks and commensurate benefits has been arrived at by society. By observing society's behavior towards risk, a quantitative relationship can be established between different types of risks, and between risks and benefits.

5.3.1 Comparisons of Risk-Benefit Ratios

One of the clearest examples of the rise of this societal revealed preference approach is C. Starr (1969). Starr found that the public is willing to accept voluntary risks that are roughly 1000 times greater than involuntary risks, holding benefits from the two risk taking activities constant. The Starr analysis admittedly used crude data and the results should be viewed as suggestive rather than an attempt to provide actual numbers for policy purposes.

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* The literature addressing risk characteristics includes C. Starr (1969); W. D. Rowe (1977); H. J. Otway (1977); and Fischhoff et al. (1978).

TABLE 5-1

Human Factors Affecting Public Attitude Toward Risk
(Comprehensive List from Litai, 1980)

	Factor	Dichotomous Values	
1.	Origin	Natural	Man-made
	Volition	Voluntary	Involuntary
	Effect Manifestation	Immediate	Delayed
	Severity	Ordinary	Catastrophic
5.	Controllability	Controllable	Uncontrollable
	Mitigation	Practical	Impractical
	Reversibility	Reversible	Irreversible
	Managability	Managable	Unmanagable
	Benefit	Clear	Not Clear
10.	Value	Good for Money	Bad for Money
	Exposure Pattern	Continuous	Occasional
	Exposed Group Size	Large	Small
	Necessity	Necessary	Luxury
	Alternatives	Yes	No
15.	Familiarity/Understanding	Familiar/Old	Unfamiliar/New
	"Dread"	Common Hazard	"Dread" Hazard
	Sensitivity	Affects av. People	Affects sens. People
	Involvement	Occupational	Non-occupational
	Triggering	"Natural"	Man
20.	Victim Identity	Statistical	Identifiable
	Societal Environment	Developed Country	Developing Country
	Economical Environment	Rich Country	Poor Country
	Political Environment	Democratic Society	Totalitarian Society
	Societal Group Involved	Civilian	Military
25.	Circumstances	Normal	Emergency
	Nature of Concern	Physical Risk Only	Multiple* (Societal)

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* Includes all other societal concerns: misuses, ecology, aesthetics, etc.

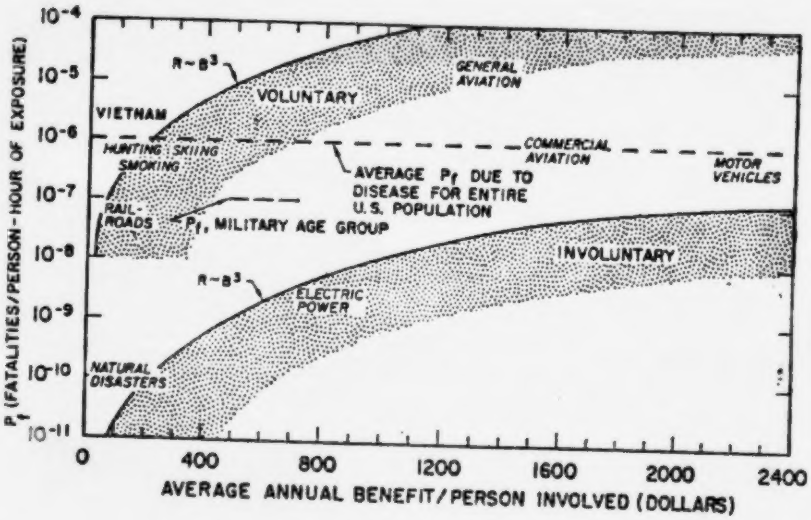
The method used by Starr was to develop quantitative correlations between the risk-benefit ratios associated with different activities. The risk measure used was the statistical probability of fatalities per hour exposure to the activity. Starr rejected the use of an index of all injuries due to the difficulty in obtaining data and the range of pain and disability associated with different injuries. The estimates of social benefits for the different activities were expressed in terms of annual dollars. In the case of "voluntary" activities, the amount of money spent on the activity was used as an estimate of the benefits (e.g., hunting and smoking). For transportation benefits, the monetary cost and time saved by the particular mode relative to a slower competitive mode (e.g., airplanes compared to automobiles) was taken as a measure of the benefits. In the case of involuntary activities (e.g., electric power), an estimate of the contribution of the activity to the individual's annual income was used. The final piece of data used in Starr's analysis was a correlation between mining accidents and injuries. The severity rate of injuries was found to be roughly approximated by a third power function of wages (i.e., the miners' risk level was proportional to wages raised to the third power: $\text{risk} \sim \text{wages}^3$). With these data, Starr compiled the risk comparison relationship shown in Figure 5-1.

There are two ways to interpret Figure 5-1. One way is to hold risk constant and examine the level of benefits required to induce individuals to accept the associated risk. Choosing a risk level of 1×10^{-7}, Figure 5-1 shows that the annual benefits must be approximately $100 per year before an individual is willing to accept that level of voluntary risks. If the 10^{-7} risks are viewed as involuntary, then the individual requires compensation on the order of $2000 per year. Another way to make the comparison is to hold benefits constant and examine the risk level acceptable to individuals. Choosing an annual average benefit level of $400 per person, Figure 5-1 shows that an acceptable level of voluntary risk would be 1×10^{-5}, but the acceptable level of involuntary risk would be 1×10^{-9}. This comparison indicates that society is far more willing to accept voluntary risks than involuntary risks.

The proper interpretation of Starr's risk-benefit comparisons is problematic. The data used in the comparison are extremely rough and in some cases questionable. For example, using both the money spent on air travel as well as the value of time saved over automobiles may be double counting the benefits. The willingness of individuals to pay the higher costs of airplane travel is at least partially due to the value of the time they save. Also, the use of expenditures for measuring the benefits of hunting and smoking

FIGURE 5-1

Risk (R) Plotted Relative to Benefit (B) for Various Kinds of Voluntary and Involuntary Exposure



Source: Starr (1969)

is at best only the lower bound since it ignores any consumer surplus. For example, individuals may be willing to pay costs in excess of their current levels to engage in hunting and smoking. Taking this into account could greatly increase the benefit-risk ratio of these activities. This would tend to reduce the apparent disparity between benefits required to undertake voluntary risks and benefits required to undertake involuntary risks observed by Starr.

The Starr comparison is based on only eight data points: four voluntary activities (general aviation, railroad travel, skiing, and hunting), four involuntary activities (natural hazards, electric power, commercial aviation, and motor vehicles). Two additional risks were included as benchmarks. The risks associated with the Vietnam war (which were classified as a voluntary risks with benefits of \$30 x 10^9 based on the annual expenditure) and the risks from all disease were used as reference points. Starr's comparison has been criticized by several researchers (Otway and Cohen, 1975; and Fischhoff et al., 1979). These studies showed that regression lines could be fit to the Starr data in several different ways yielding diverse results. Otway and Cohen (1975) fit regression lines for the data and found that there does appear to be a greater tendency to accept voluntary risks as opposed to involuntary risks; however, the difference between acceptance of these two kinds of risks was considerably smaller than found by Starr and diminished to zero as benefits increased.

Extensive analysis of the few data points compiled by Starr is probably not warranted. They should be viewed as generating plausible hypotheses that deserve testing in a more detailed study. Fischhoff et al. (1979) extend Starr's conceptual approach to the comparison of the risks and benefits of 25 activities and technologies. The results are shown in Figure 5-2. Again, individuals appear to be more willing to accept voluntary risks; however, the data points are quite dispersed.

5.3.2 Risk Conversion Factors

Rowe (1977) and Litai (1980) develop risk conversion factors to compare different types of risks. Their approaches must be carefully distinguished from those used by Starr (1969), Otway and Cohen (1975), and Fischhoff et al. (1979) since the benefits of incurring the risks play no part in the analysis. The focus is only on comparisons across the different levels of risk individuals are willing to accept, without regard to benefits.

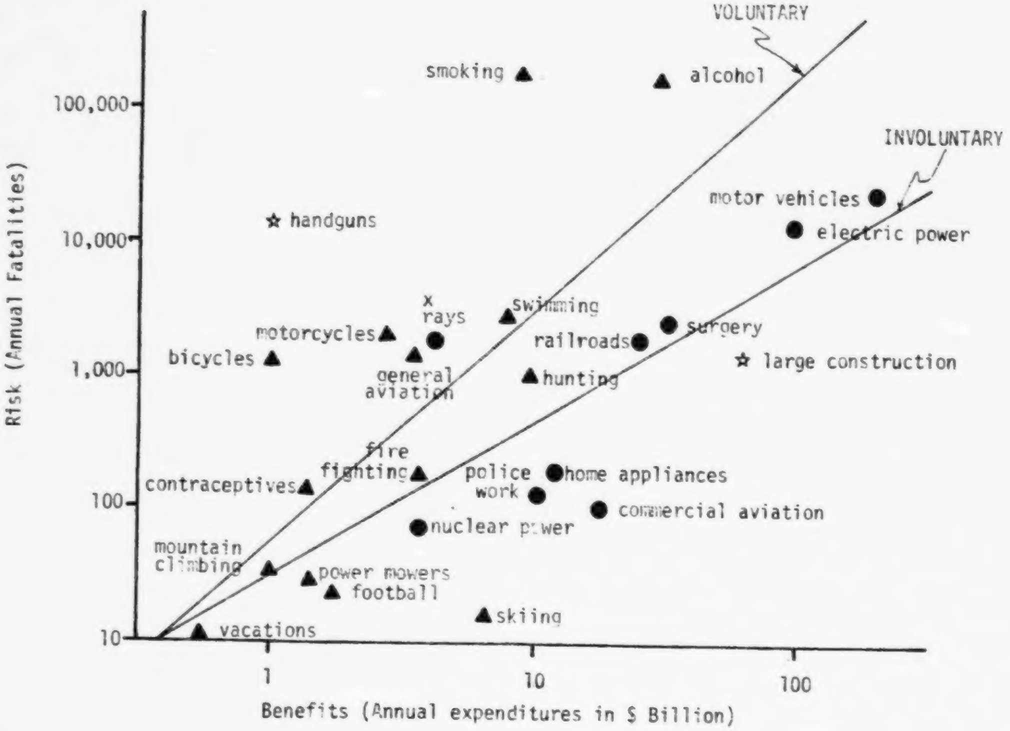


Figure 5-2

One possible assessment of current risks and benefits from 25 Activities and technologies

Items are marked with a triangle (▲) if voluntary, with a circle (●) if involuntary. Handguns and large construction cannot be classified as primarily voluntary or involuntary. They are marked with a star (☆) and are not included in the calculation of the two regression lines shown in the figure (from Fischoff et al, 1979).

The Litai (1980) study will be the focus of this discussion. The differences between the Litai and Rowe approaches is that Litai works with actual distributions of risks while Rowe uses only average risk levels. Otherwise, the two approaches are similar.

The premise of the Litai (1980) study is similar to Starr's revealed social preference approach. They both assume that by trial and error society has arrived at a rough balancing of various risks. Litai also observes that for each risk type, the actual risk level for separate individuals is spread over a wide range, often extending over several orders of magnitude. In addition, the process by which society and individuals determine the level of acceptable risk involves a number of human factors encompassing philosophical and psychological factors, as well as potential damage to property and materials. The risks classified by Litai were those where fatalities were considered to be the predominant concern.

The method used by Litai is based on actuarial risk data and therefore the data are derived from the actual behavior of people. Litai felt that the 26 characteristics listed in Table 5-1 could be summarized by the nine characteristics presented in Table 5-2. A dichotomous scale was used in assigning the risk characteristics. This means that with respect to the characteristic volition, for example, the risk is classified as either voluntary or involuntary. Litai argued that this dichotomous classification is an underestimate of human sensitivity, but is a valid approximation with abundant examples of its use in the literature. The assumption is that individuals do not perceive small changes in the parameters and, therefore, a dichotomous representation is a satisfactory approximation.

The first step in Litai's analysis was to classify all the risks by the nine characteristics. In most cases he felt there was a clear choice regarding the characteristics the majority of individuals would assign to each risk. For example, automobile travel was assigned the following nine characteristics: voluntary, ordinary, man-made, immediate, continuous, controllable, old, clear, and necessary. While it is not clear that every person would pick these exact characteristics, it was felt that they represent the opinions of the vast majority. In cases where the assignment of characteristics was not clear (e.g., homicides), the risks were not used. Some risks could be classified in both categories. For example, nuclear energy could have both immediate and delayed fatalities; then, both classifications were assigned to that risk.

TABLE 5-2

Risk Characteristics Used by Litai (1980)

Characteristic	Classification	
Volition	Voluntary	Involuntary
Severity	Ordinary	Catastrophic
Origin	Natural	Man-made
Effect manifestation	Immediate	Delayed
Exposure Pattern	Continuous	Occasional
Controllability	Controllable	Uncontrollable
Familiarity	Old	New
Benefit	Clear	Unclear
Necessity	Necessary	Luxury

The next step was to search for risks that only differed with respect to one characteristic. The specific risks used in this analysis are shown in Table 5-3. Also, the central parameters of the risk distributions are shown in Table 5-3. The error factor, according to Litai, "might reasonably be interpreted as the range of values for various groups in society." In certain cases, the data were not sufficient to develop a distribution for a specific risk. When this was the case an error factor of 10 was assigned since it was "typical" for most of the cases where data were available. Litai emphasizes that only widespread risks that involve or concern a significant portion of society may be used to represent risk categories. For example, aviation accidents to crew members are too specific to be used for general inference.

The risk conversion factors were estimated by dividing one risk distribution by another risk distribution that varied in only one of the characteristics. Log normal distributions were used to represent the distribution for each risk since the quotient of two log normals is also a log normal. For example, the risk conversion factor for ordinary-catastrophic risk characteristics was obtained by using involuntary-ordinary risks represented by pedestrian-on-sidewalk accidents and involuntary-catastrophic accidents represented by industrial catastrophies. The ratio of the two risk categories gave an estimate of the difference due to the ordinary-catastrophic characteristic. This was approximately 30 (see Table 5-4).

Table 5-4 shows the risk conversion factors that were calculated for each characteristic. Table 5-5 shows the comparisons used to estimate the risk conversion factors. These risk conversion factors can be used to calculate mean values of each risk type accepted by U.S. society. These are shown in Table 5-6. Litai points out that the values in Table 5-6 cannot be viewed as currently acceptable risks when subgroups in the populations are affected differently. These risk levels are average values of a distribution and many groups may accept substantially lower or higher risk levels. A potential use of these risk conversion factors is to make different types of risk comparable. According to Litai, the risk conversion factors can be used to show why society spends "unreasonable" sums to avert selected deaths and refuses to spend less money in other circumstances. Also, the risk conversion values were felt to be dynamic in that updating of their values was expected to be necessary.

The usefulness of these risk conversion factors in policy analysis is questionable. As calculated by Rowe (1977) and Litai (1980), they do not consider the benefits of incurring

TABLE 5-3

Summary of Acceptable Risk Data (Litai, 1980)

Specific Risk Used to Obtain the Acceptable Risk	Central Value of Acceptable Risk Distribution (fatalities/person-year)		Error-Factor
	Median	Mean	
Homicide	1×10^{-4}	9×10^{-5}	4
Occupational Risks	6×10^{-5}	1.4×10^{-4}	7
Delayed Occupational Risks	2×10^{-3}	3×10^{-3}	6.5
Smoking	4×10^{-3}	6×10^{-3}	3
Recreational Activities		2×10^{-4}	NA
Commercial Aviation		10^{-6}	NA
Industrial Disasters		$5 \times 10^{-8} - 10^{-7}$	NA
Aircraft Falling on People		10^{-8}	NA
Natural Climatic Catastrophes		1.5×10^{-6}	NA
Pedestrians on Sidewalk		2.5×10^{-6}	NA
Industrial Pollution		$5 \times 10^{-6} - 2 \times 10^{-4}$	NA
Contraceptives		2×10^{-5}	NA

NA = not available

TABLE 5-4
Risk Conversion Factors (Litai, 1980)

Risk Characteristics	RCF Estimated Value*	Probable Error Factor
Delayed/Immediate	30	10
Necessary/Luxury	1	10
Ordinary/Catastrophic	30	10
Natural/Man-made	20	10
Voluntary/Involuntary	100	10
Controllable/Uncontrollable	5	10
Occasional/Continuous	1	10
Old/New	10	10

* These mean, for example, that immediate risks require 30 times more compensation than delayed risks.

TABLE 5-5
Comparisons Used in Estimating Risk Conversion Factors (Litai, 1980)

20 Risk Factor	10 Data Used
Delayed-Immediate	Occupational Immediate - Occupational Delayed Recreation Immediate - Smoking
Necessary-Luxury	Occupational Delayed - Smoking Occupational Immediate - Recreation
Ordinary-Catastrophic	Pedestrian - Industrial Catastrophy Mining Ordinary - Mining Catastrophy Water Transport Ordinary - Water Transport Catastrophy
Uncontrollable-Controllable	People killed on ground in - Industrial Catastrophy Aircraft Catastrophy
Voluntary-Involuntary	Occupational Immediate - Pedestrian Occupational Delayed - Industrial Pollution
Natural-Man-made	Weather Catastrophy - Industrial Catastrophy Earthquake - People killed on ground in Aircraft Catastrophe
Occasional-Continuous	Elective Surgery - Occupational Immediate
Old-New	Recreation - Oral Contraceptive
Clear-Unclear	No data applicable

TABLE 5- 6

Mean Values for Risk Types Accepted by U.S. Society (Litai, 1980)

			Controllable Risk				Uncontrollable Risk			
			Ordinary		Catastrophic		Ordinary		Catastrophic	
			Immediate Risk	Delayed Risk	Immediate Risk	Delayed Risk	Immediate Risk	Delayed Risk	Immediate Risk	Delayed Risk
Man-Made Hazard	Involuntary	Old Risk	$1.3\text{x}10^{-6}$	$4\text{x}10^{-5}$	$5\text{x}10^{-8}$	$1.5\text{x}10^{-6}$	$3\text{x}10^{-7}$	10^{-5}	10^{-8}	$3\text{x}10^{-7}$
		New Risk	$1.3\text{x}10^{-7}$	$4\text{x}10^{-6}$	$5\text{x}10^{-9}$	$1.5\text{x}10^{-7}$	$3\text{x}10^{-8}$	10^{-6}	10^{-9}	$3\text{x}10^{-8}$
	Voluntary	Old Risk	$1.3\text{x}10^{-4}$	$4\text{x}10^{-3}$	$5\text{x}10^{-6}$	$1.5\text{x}10^{-4}$	$3\text{x}10^{-5}$	10^{-3}	10^{-6}	$3\text{x}10^{-5}$
		New Risk	$1.3\text{x}10^{-5}$	$4\text{x}10^{-4}$	$5\text{x}10^{-7}$	$1.5\text{x}10^{-5}$	$3\text{x}10^{-6}$	10^{-4}	10^{-7}	$3\text{x}10^{-6}$
Natural Hazard	Involuntary	Old Risk	$3\text{x}10^{-5}$(?)	10^{-3}(?)	10^{-6}	-	$6\text{x}10^{-6}$(?)	$2\text{x}10^{-4}$(?)	$2\text{x}10^{-7}$(?)	-

the risks. If the benefits of one of the risks (say, Risk 1) are 100 times higher than the benefits of a second risk category (Risk 2) used to construct the ratio, then it would not be surprising that individuals would be more willing to accept higher levels of Risk 1. The implicit assumption incorporated in the use of these risk conversion factors is that the marginal benefits associated with an additional increment of each risk type are equal across all risks. This is not likely to be the case since risk is only one attribute of a product or activity comprised of a number of attributes of varying levels. Marginal utility may be equated across all products or activities purchased by an individual, but, since risk will tend to be fixed or at least not infinitely variable within activities, there is no reason to assume that marginal benefits of incremental risks will be equated across activities. Thus, the different magnitudes of benefits associated with different types of risks could well account for substantial portions of the risk conversion factors found by Litai. This is particularly true since many of these risk conversion factors are based on the quotient of only two risk types. Still, if it were possible to gather data on benefits associated with the different risk types, better estimates of risk conversion factors could possibly be obtained.

5.3.3 Conclusions Regarding the Valuation of Different Risk Types

The evidence accumulated by the studies that have researched this topic indicates that society may place different values on different types of risks. The available empirical data are suggestive of these differential valuations and possibly indicate the likely sign of risk conversion factors, but the usefulness of these quantitative results in policy analysis is limited.

Contrary to Litai (1980, p. 116), the risk conversion factors and comparative risk-benefit ratios do not "indicate why society spends" different sums of money to reduce different types of risk. This revealed preference approach only indicates that society does appear to act as if different risks have different values. The "why" is still an interesting question. One possible reason could be the existence of certain psychic costs with different types of risks and differences in how the risks are perceived. Another reason could be that benefits have been poorly measured in these comparisons. Going back to Starr's and Fischhoff's et al. analyses, the use of gross expenditures on cigarettes and motorcycles may dramatically underestimate the benefits associated with these "voluntary" activities. If properly accounted for, these risk-benefit ratios might be considerably lower and, therefore, closer to the risk-benefit ratios of activities or products associated with "involuntary" risks. Related to the proper accounting of benefits in these studies, it may be the case that individuals value the flexibility associated with the acceptance of voluntary risks. Voluntary risks are usually associated with activities that could be discontinued in the future if the individual's risk preference structure were to change. This is not the case with many involuntary risks (e.g., the widespread use of nuclear power). The flexibility associated with voluntary activities allows individuals to appropriately balance their risk portfolios under a wide range of future circumstances. This implies that there may be some form of option value associated with voluntary risks that is not present with involuntary risks. All of these factors could contribute in varying proportions to the observed risk taking behavior examined in these studies.

A final point to be made is that all of these studies assume that society, through a trial and error process, has arrived at some sort of satisfactory equilibrium with respect to balancing different types of risks and benefits. If the individuals who collectively decide on society's risk taking base these decisions on biased information regarding the risks associated with different activities (e.g., from the news media), an undesirable equilibrium may result. Further, if individuals are poor probability processors, this situation could be aggravated. Thaler (1982) points out that "most individuals are rather poor at budgeting their money but would not want the government to emulate their ineptness." They may prefer having an expert make their life-saving decisions for them just as they would hire an accountant to do their budgeting if they could do so cheaply.

5.4 MEASURING AND DEFINING RISKS TO LIFE AND SAFETY

This section discusses several dimensions of risks to life and safety that are important for policy assessment but have been only minimally addressed in empirical studies performed to date. The studies reviewed in Chapters 2, 3, and 4 have primarily considered only risks of death defined as the number of statistical lives lost. Three alternatives or additional considerations are examined in this section. The first is a suggestion by Zeckhauser and Shepard (1976) that expected years of additional life, adjusted for expected quality of life, be used as the measure of a change in risks to life. The second issue addressed in this section concerns a suggested procedure for incorporating externalities associated with risks (ie., indirect effects on others of society) and collective risk aversion with respect to catastrophic accidents. This has been discussed in the operations research and decision analysis literature where the problem is tackled by using a multiattribute utility function. The third issue is the consideration of risks of nonfatal injuries or health problems.

Each of these topics is briefly introduced and discussed. In most cases, very little empirical work has been done that is relevant to policy questions concerning environmental risks to public health and safety. In each case, however, the issues raised are important and may provide a fruitful avenue for future empirical research.

5.4.1 Quality of Life Adjustments

Several articles have discussed the appropriate measures for the analysis of policies designed to reduce mortality risks. The two most often used measures are number of lives saved and years of life preserved. The selection of the measure of mortality benefits can affect the policy decision where one policy is preferred if the benefit unit is total lives saved while another policy is preferred if the unit is total additional years of life. In most actual policy assessment applications, the unit used has been the number of statistical lives lost or saved. The use of total lives saved is due primarily to the existence of empirical estimates for the value of a statistical life from the wage-risk studies (eg., Thaler and Rosen, 1975) and the consumer behavior studies (eg., Blomquist, 1979, and Dardis, 1980). One approach suggested by Zeckhauser and Shepard (1976) uses as its unit of measure years of additional life adjusted for the quality of life during those years. This quality of life adjustment could be particularly important for comparing risks of fatalities that are preceded by a lengthly illness with the risk of instant death.

The unit of measure in the Zeckhauser and Shepard work is the quality-adjusted life year (referred to as a QALY). QALYs are tallied on a year by year basis with a stream of QALYs represented as $q_1, ..., q_i$ where q_i is a QALY received in year i. The QALYs could be dimensioned on a number of scales. Zeckhauser and Shepard propose they be calibrated using a von Neumann-Morgenstern utility function. They use a simple example to illustrate how this is done. A year with full function (i.e. no health impairments) would be assigned a QALY with the value of 1, and a year without life a QALY with the value of 0. Calibration of QALY values for years with partial impairment requires more information. For example, consider an individual who has a choice between living the rest of his life with a specific impairment or having an operation that could return full function, while leaving his expected life span unchanged. The operation has a probability X of being successful and a probability 1-X of being immediately fatal. The value of X that would leave the patient indifferent between having or not having the operation is the appropriate value for the QALY adjusted for that specific level of impairment. For policies that will have different levels of impairment in different years, the QALY value for each year must be scaled. Also, the prior example assumes that age is not a factor in the quality of life valuation. If age does affect the QALY value, then the QALY value for each year would have to be calibrated separately.

Once the QALY values for each year that would be affected by the policy have been determined, they can be used in a utility function. The von Neumann-Morgenstern utility function is:

$$v_1(q_1) + v_2(q_2) + \ldots + v_1(q_i) = k_1 q_1 + k_2 q_2 + \ldots + k_i q_i$$

This linear utility function assumes that individuals have constant rates of tradeoffs between QALYs in different periods. The weights ($k_1 \ldots k_i$) represent the time preference for receiving QALYs. For example, the k_i's would show whether an individual facing a situation where one of the next two years would have some impairment while the other would be full function would prefer to have the full function year first or second. The question is whether there should be a discount rate applied to future QALY years. Some individuals may have preferences that would call for discounting.* In the framework set up by Zeckhauser and Shepard, the discount rate could be estimated by comparing the scaled QALY values for different time periods.

Once these QALY streams are ascertained for individuals, they must be aggregated to provide data for social policies. Welfare economics does not provide an unambiguous answer. Instead, Zeckhauser and Shepard suggest the simple approach of summing up all the QALYS.

The basic approach outlined by Zeckhauser and Shepard is that the most appropriate measure for benefits of policies to reduce health hazards is in terms of quantity and quality. Their paper provided some sample applications of the technique with the QALY values based on reasonable, but arbitrary, scalings. In one application using a related technique, Weinstein and Stason (1976) estimated the expenditures per QALY obtained from treatment for hypertension to be in the range of $3,000 to $20,000.*

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* For example, one of the paired risk attributes examined in Litai (1980) and discussed in Section 5.3 was delayed versus present. Litai found delayed risks to be valued less in his framework of risk conversion factors.

5.4.2 The Potential Usefulness of Decision Analytic Approaches.

Many of the empirical approaches have, most often due to limited data, been able to address only one dimension of the multi-dimensional risk valuation problem. That one dimension is the individual's willingness to pay for a reduction in the risk of death. However, there are externalities that could be important to the benefits calculation. These would include the value family members and others put on an individual's life and the indirect economic impacts that can affect society due to a large catastrophy with many fatalities, such as a dam break or airplane accident. Keeney (1980) argues that risks where the result may be a large number of fatalities cause greater political, economic and social turmoil.

For benefit-cost approaches to be more useful to policy makers, it is important that some of these additional levels of complexity be included in the analysis. Several recent contributions to the literature that have their roots in the fields of operations research and decision analysis offer some organizing principles that may be helpful in addressing some of these complexities. The basic approach is similar to the QALY adjustment just discussed. The first step is to develop a utility function that contains the different dimensions of risk that need to be valued. These dimensions could include the potential number of lives lost in a single incident (a catastrophy dimension), whether the risks are voluntary or involuntary, and externalities such as the effect on others. Once these dimensions are specified in a utility function with the standard properties, then the variables in the function are scaled and the constants specified in a manner similar to that used to scale QALYs in the Zeckhauser and Shepard work. All of these approaches require subjective scaling of variables and valuation of the constants through an elicitation process where either decision makers or individuals are asked to judgementally estimate these parameters. Two examples of decision analytic approaches are Bodily (1980) and Keeney (1980).

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* Other related studies that use different measures of health that could be useful in inferring a quality of life index are Franshel and Bush (1970) and Torrance (1976).

Bodily (1980) develops an approach to deal with several characteristics of risks and public attitudes that influence the value of safety programs. The characteristics that Bodily includes are:

1. Individual risk preferences
2. Nonstandard background risks
3. The need to compare the value of life saving with that of injury prevention
4. Bunching effects, where one incident involving n-individuals may be perceived as more serious than n incidents each involving one individual
5. Distinction between voluntary and involuntary risks
6. Possible psychological effects of risks

Considering a few of these characteristics, Bodily observes that the social reaction to fatalities or injuries seems to be greater when a large number of people are affected in a single accident than when the same number of people are injured in several smaller incidents. Labeling this collective risk aversion, Bodily uses this to explain why safety standards in jumbo jets tend to be stricter than for smaller air craft.

Bodily also felt that a method for comparing safety programs must also deal with the less tangible psychological effects of some alternatives. For example, risks related to the use of nuclear materials seem to introduce special kinds of anxieties above the effects that could be predicted simply due to the risk level. Bodily argues that when these psychological factors exist, they should not be ignored by the risk valuation methodology.

The basic framework used by Bodily is:

$$E = \sum_i Vi + w\,C$$

where:

E = the value of a specific safety program

Vi = the willingness to pay of individual i for probabilistic changes in his own health status, based on individual preferences.

C = the collective desirability of risk reduction based on the aggregate effect on group members of risks to others.

w = the weight applied to collective considerations relative to the dollars of individuals' willingness to pay.

Bodily then expands on this general framework. In developing the individual's willingness to pay, it is assumed that the individual considers the health effects to himself only. The collective analysis does not consider the identity of specific individuals at risk. Preferences used in the collective analysis are based on the aggregate feelings of group members about the loss of life and limb of other group members. Bodily recommends that the value of the weighting term (w) comparing the valuation of individuals relative to collective considerations be set by elected governmental decision makers, since they are representatives of their constituencies.

Athough, this short description of the framework in Bodily (1980) does not do justice to the depth of his analysis, it is descriptive of the type of method common to decision analysis. Of course, the use of weights whose values must be explicitly determined by governmental decision makers poses a potential problem. Many may be averse to making these explicit valuations, particularly if these valuations were to be made publicly. Still, implicitly or explicitly, these comparisons and tradeoffs are made. The premise of decision analysis is that the explicit consideration of these tradeoffs will allow better, more consistent decisions to be made. An interesting area of investigation might be an evaluation of the use of these decision analytic based utility functions in analyzing EPA programs affecting risks. This could be done in terms of the acceptability of the process to decison makers and affected parties as well as whether better decisions will indeed be made.

5.4.3 Valuing Nonfatal Risks

This review has emphasized empirical estimates of the value of preventing fatalities, but this may not be the most important concern for environmental policy. Many environmental issues concern the prevention of illnesses and discomforts that are not fatal. An important consideration will therefore be the value of preventing or reducing risks of morbidity.

The bulk of the research that has been done concerning the value of preventing nonfatal health effects of manmade pollution has attempted to estimate the days lost from work, or otherwise restricted, attributable to effects of pollution. These lost or retricted days have then been valued according to the lost productive activity (typically measured as the individual's daily income) and in some cases the medical costs of the illness have been added as well.* Most applications have made extensive use of the work by Cooper and Rice (1976) which provides estimates of income lost and medical expenditures incurred due to a variety of illnesses. A basic problem with this approach is that it does not measure willingness to pay to prevent morbidity. It is not even clear that income and medical expenditure would be a lower bound on the individual's willingness to pay because in many cases the individual may receive sick pay and insurance payments to cover these losses, although the insurance premiums must be paid. The individual's willingness to pay to prevent time spent sick is more likely to be a function of the pain and discomfort that accompanies the illness than of his wage. Pain and discomfort can also be partially offset by the utility of increased leisure when, for example, an individual is too sick to work but not too sick to enjoy reading a book. There is little empirical evidence available on this question.

Cropper (1981) developed an innovative approach to the estimation of the benefits of reduced morbidity that goes a few steps beyond the previously used approaches. She developed a model of investment in health that incorporates the possibility that the individual can influence his health with a variety of preventive health care activities. The benefits of reduced pollution are therefore the value of the reduction in time spent ill plus the value of the reduction in preventive health care activities that were being undertaken to offset the harmful effects of exposure to pollution. Cropper's estimates are double the estimates that would be derived from looking at only the time spent sick. This approach does not solve the problem of how to appropriately value the time spent sick (Cropper still uses the wage for this), but it provides a more realistic treatment of the individual's behavior with respect to the state of his health.

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* Examples using these approaches are Liu and Yu (1976) and Crocker et al. (1979). These and similar studies are briefly reviewed by Freeman (1979a).

An important question for future efforts to obtain an estimate of the value of reduced morbidity is what constitutes an appropriate measure of morbidity. The most common measure has been work days lost due to illness, but this makes no distinction between a day spent in mild discomfort and a day spent in extreme discomfort. It also does not capture days spent sick but at work. A measure that has been used for nonworkers is "restricted activity days". These are the measures that have been used in some of the surveys that have provided data for estimation efforts. These surveys include the annual Health Interview Survey by the National Center for Health Statistics (used by Ostro, forthcoming) and the Michigan Panel Study of Income Dynamics (used by Cropper, 1981).

A whole range of possible approaches to estimation of willingness to pay to prevent morbidity needs to be explored. The Cropper study provides evidence that people make observable expenditures of money and time to prevent illness. These are the kinds of tradeoffs that need to be observed in a market approach to estimate the value of reducing morbidity, such as those reviewed in Chapter 3 concerning the value of reducing mortality. Those studies may in fact provide a starting point since the activities considered involved both fatal and nonfatal risks. A few of the wage-risk studies also used measures of nonfatal injuries but the problems of overlooking worker's compensation make most of the resultant estimates questionable. Contingent market approaches might also be a fruitful avenue for obtaining estimates of willingness to pay to reduce morbidity. Questions about risks of morbidity might even be less emotion-laden and easier for respondents to consider than questions about risks of death.

5.5 PERCEPTIONS OF RISKS

All of the willingness-to-pay approaches assume that people are able to judge for themselves what the benefits of various risks are. Several avenues of psychology research suggest, however, that individuals may have trouble making consistent rational choices with respect to risks. This may be the result of poor information or differences in the alternatives that the researcher may have overlooked. Whatever the cause, these problems raise the question of whether public policy should be based on preferences revealed by individuals' behavior. The studies discussed in this section do not provide conclusive evidence one way or the other, but they raise important questions that need to be addressed in future research.

5.5.1 Biased Perceptions of Risks

There is some evidence that individuals' perceptions of risks associated with various activities may be systematically biased. If errors in individuals' perceptions of risks are random, then the explanatory power of the statistical valuations reviewed in Chapters 2 and 3 would be reduced (i.e. the standard errors of the estimates would be increased), but the estimates would be unbiased. However, if the errors vary in a systematic manner, then the estimates from these statistical studies will be biased. The contingent market approaches also rely on a consistent response by individuals to different levels and kinds of risks, although they could allow for some inconsistencies easier than the actual market approaches.

Lichtenstein et al. (1978) conducted five experiments where individuals were asked to judge the frequency of lethal events. They found individuals' judgements of risk frequencies were highly consistent but systematically biased. Two kinds of bias were identified--one, there was a tendency to overestimate risks of relatively infrequent events (e.g. death from botulism) and to underestimate the probability of more frequent events (e.g. death from heart disease); and two, a tendency to overestimate certain risks characterized by wide media exposure, memorability or the imaginability of various events. To the extent that these systematic biases are present in individuals' perceptions of risk, the results of the studies reviewed in Chapters 2 through 4 may be biased.

Even though some of the possible causes of biases in individuals' risk perceptions were identified by Lichtenstein et al., the direction of the bias this may cause in the empirical estimates still is not clear. For example, a common view is that workers in risky occupations may underestimate the probability of lethal accidents due to being uninformed of the risks. However following the Lichtenstein et al. findings, the likely bias in individuals' perception of the frequency of these low frequency occurrences would be to overestimate the risks. Further, Bailey (1979) points out that in dangerous occupations, such as logging, accidental deaths and injuries are everyday topics of conversation. Also, for every severe or fatal accident, there are many near misses. Again following Lichtenstein et al., the effect of daily conversations concerning job risks and the increased vividness and imaginability of accidents from the many near misses would tend to result in workers' overestimating job risks. Additional research on how individuals perceive the specific risks that are used in these empirical valuation studies is needed before the direction of potential risk perception biases can be identified.

5.5.2 Preference Reversal

Preference reversal in an economic context is discussed in Grether and Plott (1979), Pommerehne et al. (1982) and Reilly (1982); however the issue was first raised in the psychology literature by Lichtenstein and Slovic (1971), Lindmann (1971) and more recently, Tversky and Kahneman (1981). The basic issue is that there seems to be no theory of individual preferences that can be used to consistently explain an individual's choices among uncertain or risky outcomes. This inconsistency suggests, according to Grether and Plott, that no optimization principles of any sort underly even simple choices.

The basic example used to illustrate preference reversal is an experiment where subjects are asked to pick one lottery from among two choices as the gamble they would prefer to take. After indicating a preference for which one of the lotteries in the pair they would rather play, the subjects are then asked to assign monetary equivalents to the two lotteries. This is done by putting the subject in the position of playing each lottery and asking them the amount of money they would take with certainty rather than play the lottery. For example, an individual facing a lottery with a fifty percent chance of losing $2.00 and a fifty percent chance of winning $20.00 might say that he would take a sure five dollars rather than undertake the uncertain lottery. The preference reversal occurs when the lottery that is preferred by the subject when selecting between the two lotteries is given a lower monetary value. It is easily shown that this is inconsistent with traditional forms of preference theory.

Whether or not this is an important issue for empirical studies placing a value on risks to life depends upon the pervasiveness of the preference reversal phenomenon. The studies examining the preference reversal phenomenon have all used pairs of lotteries with essentially the same expected payoff.* For example, the first pair of lotteries examined by Grether and Plott (1979) were:

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* The only exception is Pommerehene et al. (1982) where the expected values varied by as much as 33 percent. They did find that preference reversal declined when the difference in the expected values increased. However, preference reversals were still present. Transactions were conducted with play money exchangeable at a low converted value.

	Probability of Winning	Amount if Win	Amount if Lose	Expected Value
Lottery A	35/36	$4.00	-$1.00	$3.86
Lottery B	11/36	$16.00	-$1.50	$3.85

The expected values of $3.86 and $3.85 would be nearly indistinguishable to the subjects in the experiment. As a result, these experiments show whether individuals are capable of fine tuning their risk-reward portfolios. Since there is only a small difference in the payoffs for the two lotteries, the penalties associated with an incorrect decision are very small. If preference reversal were found for a pair of lotteries with larger differences in payoffs, then this would be of greater concern. Indeed, when Pommerehne et al. (1982) increased the difference in the payoffs by up to 30 percent, the incidence of preference reversal declined.

In conclusion, the research on preference reversal has been quite limited and is deserving of more study. The evidence to date does not seem to contradict conventional preference theory. The only conclusion that seems warranted is that individuals may not be able to appropriately distinguish between risk-reward choices that have nearly the same expected payoff. If traditional preference theory is adequate for predicting choices among options that really matter, i.e., choices between options with distinctly different payoffs, then it is probably an adequate assumption in empirical risk valuation studies. Whether or not individuals can accurately select among nearly equivalent options at the margin is of far less importance.

5.5.3 Cognitive Dissonance

In an interesting and potentially important article, Akerlof and Dickens (1982) adapt another concept from psychology into an economic model. The theory of cognitive dissonance as advanced by Akerlof and Dickens is based on the concepts that individuals not only have preferences with respect to states of the world, but also have preferences regarding the specific beliefs they hold, even if these beliefs contradict available information. In other words, individuals have flexibility in the beliefs they hold and can use this flexibility to choose beliefs that maximize utility.

Akerlof and Dickens refer to a great deal of anecdotal information that suggests that workers in dangerous jobs are often quite oblivious to the dangers involved. For example, interviews with benzene workers found some workers who denied that they were working with dangerous chemicals. Another example cited was a nuclear plant where workers were given badges to measure radiation exposure; however, all workers failed to wear their badges. Akerlof and Dickens go on to construct a theoretic model of the labor market where people prefer to believe their work is safe. The worker chooses his beliefs according to whether the benefits exceed the costs. If the psychological benefit of believing one's job is safe exceeds the costs due to a real increased chance of accident, the worker will believe the job to be safe.

Akerlof and Dickens cite the psychological evidence supporting cognitive dissonance. The strength of the evidence is in the great number of experimental results easily explained by the theory. Psychology experiments show that individuals with the same information will adopt beliefs that are in accord with their natural preferences. For example, people like to view themselves as having made good decisions. Investigations have found that individuals, after having made a decision (e.g. placed a bet on a horse or selected a home appliance), systematically hold stronger beliefs regarding the appropriate choice than individuals who are just about to make the choice, even when there has been no new information. Other examples can be cited from the psychology literature.

The conclusion of Akerlof and Dickens is that with additional research cognitive dissonance can be incorporated into economic models in a predictive manner. The importance of cognitive dissonance for estimating the willingness to pay for reductions in risk is clear. The tendency for workers or consumers to ignore risks because they are better off believing the risks are lower than actual levels will distort the risk valuations that are based on individuals' revealed preferences from market behavior. For example, Dardis (1980) used the purchase of smoke detectors as a measure of the willingness to pay for increased safety. The theory of cognitive dissonance would allow individuals to obtain utility from the belief that they were perfectly safe when in their home. If this belief were adopted, then purchases of smoke detectors would be lower than what would otherwise be the case and the observed value associated with the reduction in risk underestimated. Cognitive dissonance could potentially have important ramifications for risk assessment and could well explain some of the observed differences in the valuation of different risk types addressed in Section 5.3.

6.0 CONCLUSIONS

In spite of the seemingly large amount of attention this topic has drawn, there has been no ambitious and consistent research program to quantify the willingness to pay for reductions in health risks. Analyses of the theoretical questions greatly outnumber empirical estimation efforts. The empirical estimates that do exist should best be viewed as preliminary, that is, as pointing out additional hypotheses for analysis. The purpose of much of the research was not to provide empirical estimates for use in policy analysis but to test hypotheses regarding the workings of markets, particularly the labor market. This more limited goal made it less necessary to control for biases that would change the actual value of the estimated risk premium, but not change the direction of the effect. For example, biases in workers' perceptions of risk could change the absolute value of the wage-risk premium, but not necessarily the direction of the effect on wages. The most significant contributions to valuing reductions in risk have been made by studies focusing on the Department of Labor's occupational health and safety programs. Except for this area, the research has been scattered with work being done on different types of risks in different situations, and with little followup to test hypotheses identified in earlier studies. As a result, many of the important questions for environmental policy assessments have not been addressed in the empirical work.

This conclusion should not be viewed as reducing the importance of the contributions that have been made in this research area to date. Identifying hypotheses for research, defining problems that need to be addressed, and pointing out potential biases that can be controlled in future work are important and necessary steps in a developing area of research. However, this conclusion is not encouraging for policy makers who would like to use these estimates now. Still, careful analysis of the results may provide benchmark numbers for policy assessment. Since policy decisions are presently being made that trade off expenditures for reduced risks, it is important to make the best use possible of the currently available information.

The balance of this chapter will address the identification of reasonable ranges for values of a statistical life, the general conclusions from the wage-risk studies, the consumer market studies and the contingent market studies reviewed, and suggestions for research.

6.1 THE VALUE OF LIFE ESTIMATES—IS THERE A REASONABLE RANGE?

One of the goals of this review is to summarize the available empirical information on the value of life and safety that is applicable to environmental policy questions. The results of the wage-risk studies fall into two groups: those finding $400,000 to $600,000 (1982 dollars) per statistical life and those finding $1,000,000 to $7,000,000 per statistical life saved. All three of the consumer market studies found values per statistical life saved of about $300,000 to $500,000; these fall close to the lower range of the wage-risk studies. Two of the contingent market studies that considered risks of airline travel found values of $4,000,000 to $5,000,000 per life for changes in risks at levels close to the actual risk of airline travel. A few outlying results were found by contingent market studies--Acton found $20,000 to $100,000 per life and Mulligan found $70,000 to $300,000,000 per life. The outlying Acton results can possibly be explained by the type of risk analyzed. The risk being valued was a reduction in the risk of death after having had a heart attack by improving emergency services. Since the occurrence of a heart attack is a future event, possibly many years away, and even then not certain to occur, it is not surprising his estimates of willingness to pay for a reduction in these risks are lower than other studies where immediate death from accidents or fire were considered. Other aspects of the survey design, such as the two stage presentation of the risk levels, could have caused the low responses. The very low and very high results found by Mulligan are harder to explain, but problems with the design of the survey may be the cause. Eliminating the questionable outliers, the result is two ranges of estimates--$300,000 to $600,000 and $1,000,000 to $7,000,000.

Given the wide variation in results and the estimation problems found in all of the risk valuation studies, it is difficult to select a range of estimates appropriate for a specific policy application. One attempt to roughly define this range with respect to public health and safety policy was made by Bailey (1979). In a widely read and generally excellent review, Bailey (1979) tried to obtain an intuitive feel for where within, or between, these essentially two groups of value of life estimates a reasonable estimate might fall. He performed some calculations to develop benchmarks for the value of life that might be reasonable, then applied this test of reasonableness to the estimates. Bailey concluded that the lower range of value of life estimates, as typified by the Thaler and Rosen (1975) estimates, was reasonable while the higher estimates found by, for example, R. Smith (1974, 1976) and Viscusi (1978) were outside the range of reasonableness. Unfortunately, Bailey's test of reasonableness may not be entirely reasonable.

Bailey calculated a family's willingness to pay for a given reduction in risk implied by the estimated values for a statistical life from the different studies. This willingness to pay was then compared to the average income for a family of four to see if it represented a "reasonable" fraction of their income, i.e., an expenditure that they could reasonably afford. Bailey used a reduction in annual risk of death from 6 per thousand to 5.5 per thousand for his calculations. The lower range of value of life estimates used by Bailey, characterized by the Thaler and Rosen (1975) and Dillingham (1974) results, has a lower bound of around $170,000, an intermediate value of $360,000, and upper value of about $715,000.* Bailey then multiplied these values times the reduction in risk, and then times the number of family members; i.e., value of life x reduction in risk (.0060-.0055) x family members (4). These calculations resulted in an annual household expense of $300, $700 and $1,400 using the low, intermediate and high value of life within this lower range of results. A representative family of four with an income in 1978 of $18,500 would then pay 1.6 percent, 3.8 percent or 7.6 percent of family income given this range of estimates for value of life. Bailey concluded that this appears to be a reasonable expenditure.

Bailey then considered some of the higher estimates that came from the R. Smith (1974) and Viscusi (1978) studies. Taking the highest value of $2.5 million from R. Smith (1974) as an upper bound, and adjusting this value to 1978 dollars yielded a value of approximately $5.0 million per life. Performing the same calculations gave an estimate of a willingness to pay of $10,000 for this reduction in risk for the family. This is about 55 percent of family income. Using this number, Bailey concluded that these higher value-of-life estimates are unquestionably too high.

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* All values for this discussion of Bailey's test of reasonableness are in 1978 dollars and were subjectively adjusted by Bailey to account for a number of factors that he felt were omitted in the estimation process. These included correcting for the fraction of wage premium attributable to risks of injury rather than risks of death, medical costs not borne by the family, and insurance premiums. The net result was to decrease the estimated value of a statistical life by approximately 30 percent. The primary reason for this decrease was the correction for the portion of the risk premium that is due to the risk of injury. Bailey judged that more than 56 percent of the wage-risk premium was due to the risk of injury, and this was subtracted from each study's value of life estimate to give the wage premium required by the risk of fatal accidents only. This large a reduction in the estimates may not be warranted. Some of the empirical work indicated that wage premiums for the risk of nonfatal injuries were low due to the existence of workers' compensation.

There are three problems with Bailey's test of reasonableness. First and most important, the risk reduction being considered was far beyond the range of risks considered in the empirical studies. Second, the multiplication of the willingness to pay by the number of family members was inappropriate. The estimates from the wage-risk studies are for a wage earner in the family and the willingness to pay for a reduction in risks to a wage earner may be higher than an equivalent reduction for all family members due to the potential hardship imposed on the entire family from the loss of the primary income. Third, the selection of $5 million as the upper bound for the R. Smith and Viscusi studies was misleading. This value from R. Smith's 1974 study is an outlier and suffers from several potential statistical problems. The results from R. Smith's second study are more appropriate for determining upper and lower bounds. The upper bound would then be $3 million rather than $5 million in 1978 dollars used by Bailey.

The inappropriateness of the risk change used by Bailey deserves more discussion. He used a reduction in the annual risk of death for each household member of 5 per 10,000 (5×10^{-4}). The risk levels used by R. Smith (1974, 1976), Viscusi (1978a, 1978b) and Olson (1981) ranged from approximately $.15 \times 10^{-4}$ to 3.0×10^{-4}. Thus, the change in risk used by Bailey exceeded the entire risk to individuals working in the riskiest manufacturing industry used in their data sets. The mean risk level in these studies ranged from 1.0×10^{-4} to 1.5×10^{-4}. Reducing these risks by 50 percent would be a change of between $.5 \times 10^{-4}$ and $.75 \times 10^{-4}$, a reduction that is an order of magnitude lower than the change considered by Bailey. To provide an example of how large a 5×10^{-4} change in an individual's annual risk of death is, one need only compare it to the 2.7×10^{-4} average annual risk of death in a motor vehicle accident (car, truck or bus). Bailey used a change in risk that is close to twice as large as what would be needed to entirely eliminate the risk of death in a motor vehicle accident for each family member. This is far from the marginal changes in risk to which the results of the empirical studies are applicable. Prices of many market goods would appear unreasonable when applied to quantities of the goods well above the amounts that are typically purchased.

A better test of reasonableness might consider what a family would be willing to pay to reduce by 50 percent the annual probability of the principal family wage earner being killed in a job-related accident. This would be approximately a change of between $.5 \times 10^{-4}$ and $.75 \times 10^{-4}$ in the risk of death. Using Bailey's adjusted values for Thaler and Rosen gives a range encompassing a low value of about $10.60 per year, an intermediate value of about $22.50, and a high value of about $44.70, all in 1978 dollars. Using the high value of life estimates from R. Smith (1976), we find this family would be willing to pay \$3,000,000 x .625 x 10^{-4}, or about \$188.00 per year. Presented in this manner, both the lower group of value of life estimates and the higher group of estimates seem reasonable.

Both economic theory and empirical evidence indicate that there is no reason to expect the value for a statistical life to be the same in all circumstances. It may vary depending upon the size of the change in risk being considered as well as with the initial risk level of the population being affected. Given this expectation, we will not try to say that the appropriate value for a statistical life for environmental policy purposes is a certain amount. Rather, the focus of this discussion will be whether such a value is likely to be greater than or less than the estimated values for a statistical life available to date.

In this effort, the wage-risk studies will be emphasized since as a group these are the most credible studies that have been done. These studies have consistently found a significant relationship between on-the-job risks and wages. This is a relationship that makes sense theoretically and is easy to believe exists. The consumer market studies have examined risk choices that are credible, but none of the results have been validated by repeated estimation in the same market. They are all subject to potential errors in the assumptions that were used to quantify the benefits of incurring the risks, or from reductions in risk. Also, these studies were unable to separate willingness to pay for reductions in the risks of death from risks of injury and property damage. For example, the Blomquist (1979) study is based on the assumption that the time it takes to buckle and unbuckle a seat belt is one basis for the individual's decision to use or not to use seat belts. The contingent market studies performed to date have not used state-of-the-art techniques and the results are potentially subject to a great deal of error. The most carefully performed contingent valuation study was Acton (1973), but he investigated the willingness to pay for post heart attack emergency services. This risk, conditional on having a heart attack, is difficult to relate to risk levels and health outcomes of other studies.

The wage-risk studies alone still give a range of \$400,000 to \$7,000,000 in 1982 dollars per statistical life. However, these estimates can be used to establish bounds on the value appropriate for environmental risks if the direction of the expected biases can be uncovered and are uniform in the same direction.* If, for example, a lower bound can be established, then if the lower bound benefits of a program exceed the estimated costs, one would be reasonably confident that the program was in fact worthwhile.

The lower range of estimates from the wage-risk studies is from $400,000 to $600,000. This could be considered to be a rough lower bound to the value of a life for use in policy assessment if the directions of identified biases in the estimates are all downward. Unfortunately, the potential biases that have been identified are in both directions and may be large. Still, we are willing to argue that, subject to one critical uncertainty, these lower wage-risk estimates (i.e., $400,000 to $600,000) for the value of a life are likely to provide a lower bound to the value of preventing the life threatening risks that need to be considered in environmental policy assessment.

The key potential sources of biases that have been identified in these wage-risk studies are:

1. Whether the workers accurately perceive the risks of different occupations.

2. Whether the workers in the occupations examined are more or less risk averse than the general public.

3. Whether characteristics of occupational risks, such as voluntary versus involuntary or delayed versus immediate as discussed in Litai (1980) and Starr (1969), make the wage-risk estimates different from what the estimates for environmental risks would be.

4. Whether the wage-risk premium captures only the risk of mortality rather than risks of both nonfatal and fatal injuries.

5. Whether potentially important explanatory variables have been omitted from the estimated equation and, therefore, bias the results significantly.

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*The results of consumer market studies are close to or within the lower end of this range, but the potential biases in these results relative to a value for environmental risks are different than for the wage-risk studies.

Of these five potential sources of biases, the first three are more likely, in our opinion, to result in a downward bias on the value of life estimates. The first source, workers' perceptions of risk, can in theory bias the estimated risk valuations up or down if worker perceptions show a systematic bias. There is, however, some evidence that workers are at least able to roughly rank jobs by their riskiness.* Still, there is likely to be considerable error in individuals' judgements of the actual amount of risk associated with different industries and occupations. This will have two effects on the results of wage-risk studies: one, the error-in-variables problem will reduce the significance of the coefficients on the risk variable; and two, the workers who tend to underestimate the risks of a particular occupation will gravitate to that job because they will be willing to accept a lower wage-risk premium.** This second effect will tend to produce a downward bias in the estimated value for a statistical life.

The second identified source of bias should clearly have a downward effect on the wage-risk premium. Most of the hedonic wage-risk studies that produced estimates in this low range used a data set comprised of the higher-risk occupations. It is generally hypothesized that less risk averse individuals will tend to take these jobs. This has been offered as one explanation for the different estimates of wage-risk premiums that have come from different data sets. If there is a bias, it would seem to be downward.

The third source of bias concerns different risk characteristics. Many environmental risks have different characteristics than those related to accidents on the job. In particular, there is some speculative evidence that the willingness to pay to avoid involuntary risks, i.e., risks over which the individual has little control, are greater than for voluntary risks. Although the characterization of risks as voluntary or involuntary is often not clear,*** it would seem that the decision to take a job would be more voluntary than most environmental risks.

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* Viscusi (1978a) presented data on whether the worker considered his job dangerous.

** This was discussed in Section 2.4.3.

*** For example, the risks of death in a commercial airline is considered to be an involuntary risk in most studies; however, a person could refuse to fly. Nuclear power plants are cited as another example of involuntary risks, but again people could move to a different location.

The fourth and fifth identified sources of biases pose a problem because they will tend to result in an upward bias in the estimated value of a life. The fact that the risk premium may be capturing the compensation for risks of nonfatal as well as fatal accidents has a clear upward bias on the estimate; however, the extent of this bias is not clear. R. Smith (1974, 1976) was unable to find a statistically significant risk premium associated with nonfatal injuries indicating that workers' compensation may be adequate to compensate for the potential loss and no wage premium is required. Olson (1981) and Viscusi (1978b) were able to isolate the effects of nonfatal risks on the wage premium. In these cases, the estimated risk premium for fatal injuries was still in excess of $600,000. These results indicate that this potential upward bias, if it does exist, is probably not large.

The fifth potential source of bias is the most significant problem. The willingness-to-pay estimates for changes in the risk of fatal accidents obtained from the hedonic wage-risk studies probably capture more than just the pure valuation of risk. High levels of risk are closely associated with a number of unpleasant working conditions, but in most cases the only measure of job unpleasantness used in the study was the risk of accident. Therefore, the hedonic wage-risk estimates probably reflect the wage premium required by that closely related package of unpleasant job characteristics, not just risk. This would produce an upward bias in the estimates.

Our conclusion is that, depending upon how one views the potential severity of the omitted variable problem in the hedonic wage-risk studies, the lower range (i.e., $400,000 to $600,000) of the value-of-life estimates from these studies probably reflects a lower bound to the value of fatal risks associated with environmental problems.

6.2 SUGGESTIONS FOR FUTURE RESEARCH

This review has indicated that there has been no ambitious research program to quantify the willingness to pay for the reduction or prevention of environmental risks. A program of this type would, of course, provide, considerable information. A detailed research plan for a comprehensive program is beyond the scope of this project. This section will identify some of the important issues that would need to be addressed in a research program and will suggest studies that could be conducted in the near term that would make the studies performed to date more useful for policy analysis.

One overriding issue is whether willingness to pay based on the revealed preferences of consumers or workers is an appropriate basis for valuing risks for use in policy assessment. Willingness to pay is the appropriate measure if it is based on accurate perceptions of risks by individuals and revealed by consistent behavior in actual markets or in response to hypothetical markets. However, the observations on human behavior that are used to generate willingness-to-pay estimates for reducing risks are subject to many potential emotional and informational biases. If individuals act irrationally with respect to certain risks, then should environmental policy follow the same irrational principles? Thaler (1982) made the point that "most individuals are rather poor at budgeting their money, but would not want the government to emulate this ineptness."

The discrepancy between the avoidance of voluntary and involuntary risks found by Starr (1969) and Litai (1980) is an example of where it may not be desirable to have policy follow revealed preferences. Although both studies suffer from severe data limitations and theoretic shortcomings, they have offered evidence that individuals value voluntary and involuntary risks differently. If a policy is adopted by the government that allocates more money for reducing "involuntary" risks than "voluntary" risks,* then more fatalities will occur than if this characteristic did not influence the allocation of revenues. Before such a policy would be adopted, it would be important to determine whether the government is simply adopting the irrational behavior of individuals or if there really are countervailing benefits such as reduced psychological stress that make involuntary risks a bigger burden to society.

The conclusion that results from the above argument is that future research should try to better incorporate psychological findings within willingness-to-pay studies. Before willingness-to-pay estimates based on revealed preference are used in policy studies, a better understanding of the reasons for choices made by individuals to reduce or incur risks is needed. The work on probability judgements by Lichtenstein et al. (1978) and the work on cognitive dissonance by Akerlof and Dickens (1982) would be useful starting points for this type of analysis. A topic related to this is whether or not people value risks with different characteristics differently and, if they do, why? The most promising approach for obtaining some of this information seems to be a melding of the contingent valuation methods used by economists with the surveys used by psychologists in their research on risk perception and decision making. The contingent valuation studies performed to date have not, on the whole, been well implemented. Contingent market approaches provide a great deal of flexibility to pursue valuation questions specific to environmental policy decisions and to probe people's attitudes and preferences regarding the acceptability of certain risks.

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* Again, recognize that it is hard to clearly differentiate between voluntary and involuntary risks.

Another area of research that could be fruitful is the use of utility functions as a means of organizing the valuation problem for a specific environmental risk. The basic approach is illustrated by Keeney (1980) and Bodily (1980). First a function is devised that incorporates all of the factors that are felt to influence the valuation of the risk. The function contains risk related variables that can be estimated such as the number of fatalities, the number of fatalities that occur at one event (to account for disasters, see Section 5.4.2), and the number and types of nonfatal effects. These variables are incorporated in a function where the constants (i.e., coefficients and exponents) are unspecified. The second step is to estimate values for these constants through a scaling process. These estimates could be obtained through use of surveys similar to those used in contingent market studies. As a result, decision theory approaches are actually very similar to the contingent market surveys used by economists. There is no reason why the constant terms in a decision theory framework could not be scaled in terms of dollars and incorporated in a conventional economic benefit-cost framework. A trial application of this technique could prove useful.

To summarize the other research recommendations, they will be presented by approach, i.e., hedonic wage-risk, consumer market and contingent market.

Wage-Risk Studies

The goal of many of the wage-risk studies was not to provide value of life estimates usable in environmental policy decisions, but was instead to test hypotheses regarding the operation of the labor market. Even though these studies are probably the most credible studies that have been done for valuing risks, it is not clear how useful these estimates are to the EPA. The types of risks that have been considered, namely accidents on the job, are not for the most part the kinds of risks that are of interest to the EPA. Transferability is difficult because we know so little about how differences in risks influence the valuation. Another problem with transferring results from wage-risk studies is that they consider only one population group. Some of the studies have considered a wide range of occupations and both men and women, but most considered only male blue-collar workers. In either case, those who are not in the labor force are not represented and how risk valuations may vary between labor force members and those who are not in the labor force, or those who are sensitive to specific environmental risks, is unknown.

Still, wage-risk studies may provide useful information. As was argued earlier, they might be useful in estimating a lower bound for many environmental risks. The principal problem with using the current wage-risk studies as a lower bound benchmark is the potential omitted variable bias resulting from the exclusion of job characteristics other than risk. Other unpleasant job characteristics, such as noise, dirt and uncomfortable temperatures, may be highly correlated with job risks.* A hedonic wage-risk study incorporating these additional variables could be useful in helping EPA determine a lower bound for the value of reducing or preventing environmental risks. Also, if risk conversion factors that could account for different risk characteristics and different populations could be determined from other studies, the results of the hedonic wage-risk studies could be transferred and used to value other risks.

Another problem area in wage-risk studies that could be corrected is that in most cases a functional form has been used that constrains the market equilibrium hedonic wage-risk function to be linear or convex. The theory indicates that a concave function is entirely possible and could be expected to occur if less risk averse workers are found in the riskier jobs. A more flexible functional form should be used in future wage-risk studies to allow the function to be either concave or convex.

Consumer Market Studies

The consumer market studies have a sound conceptual basis in that they have examined actual choices that people make with respect to risks. Data limitations have resulted in simplifying assumptions in the studies that examined risks of automobile accidents, which open the results to a great deal of question. Also, the study that examined risks of residential fires failed to use correct consumer surplus measures. The primary difficulty in consumer market approaches is that in cases where a risk is incurred in order to obtain a benefit (as in the case of automobile transportation) the benefit needs to be quantified to determine how much the consumer is having to be compensated in order to tolerate that risk. Questions also remain as to whether observed choices are based on adequate consumer information and on reasonably accurate perceptions of risks. The usefulness of future consumer market studies for addressing EPA policy questions depends on whether relevant consumer choices can be identified and whether data are available to adequately analyze these choices. A point that should be emphasized is that consumer market studies should not stand on their own. They should be augmented with surveys to validate their assumptions. For example, there are several key assumptions used by Blomquist (1979) including the assumption that the disutility of wearing a seat belt is represented in part by the time cost of fastening it. Also, in the case of Ghosh et al. (1975), the key assumption is that the benefits of driving faster can be measured by the savings in driving time. These assumptions can be validated outside the models by using surveys similar to those discussed in Slovic et al. (1977). Too often these critical underlying assumptions remain untested and the policy relevance of the results unknown.

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* Since the jobs with the highest risks are those associated with moving materials (i.e., assembly, loading and machining), it is likely that other unpleasant job conditions are correlated with job risks.

Contingent Market Studies

The contingent market studies performed to date have not used state-of-the-art techniques and the results are subject to a great deal of error. These studies do not demonstrate or adequately test the full potential of this approach for estimating the value of reducing or preventing risks. The most important challenge facing contingent market studies is presentation of the risk choices to survey respondents. More needs to be learned about people's attitudes and behaviors with respect to personal and social risks in order to design survey instruments that communicate the risks meaningfully and adequately elicit the desired information. Due to the paucity of market data concerning risk choices, contingent market techniques may be the more promising, and in some cases, the only available approach for addressing a wide range of issues.

Three general areas of improvement and development need to be pursued in future contingent market studies. These are attention to underlying economic theory, selection of types of risks to be examined, and development of implementation methodology.

Contingent market approaches are based on the economic theory of consumer behavior from which is derived certain expectations about the behavior of rational, utility maximizing individuals. Future studies need to pay attention to the expectations that theory provides about preferences toward safety in order to provide evidence concerning the validity of these expectations. The work of Tversky and Kahneman (1981) provides some alternative predictions of preferences with respect to risk taking that could be considered. Two specific areas that need attention are differences in marginal WTP for safety across individuals and the underlying causes of zero bids and refusals to respond to WTP or WTA survey questions. It could be expected that people who are at higher risk levels would be willing to pay more for a given reduction in risk than people at lower risk levels. This needs to be carefully tested. It is also expected that differences in income and other socioeconomic characteristics will influence WTP for safety. This needs to be routinely examined in any contingent market application. Changes in marginal WTP for safety as safety increases or decreases also need to be examined in order to determine if the demand for safety behaves like more ordinary market goods. Refusal to respond to the questions or zero or very large bids may signal a rejection of the premises of the questions themselves. These kinds of responses need to be probed.

The best contingent market results, in terms of consistency between actual behavior and what an individual predicts his behavior would be, have been obtained when the hypothetical questions relate to behavior that is familiar and frequently experienced by the individuals. Risks concerning transportation, water quality, sewage treatment, hazardous wastes and availability of emergency services are examples of risks that might be effectively examined. What is most important is that the topic be connected to decisions that people can imagine making.

Two areas that may be fruitful for future contingent market approaches are long latency risks of death, such as cancer, and risks of morbidity. The data constraints that make examination of long-term health effects so difficult in market studies do not constrain contingent market approaches. The link between an exposure and a risk could be hypothesized without having to be proved. Morbidity might be a very good topic for future contingent market studies because it may not face the emotional barriers that the idea of trading money for lives provokes when respondents are asked to consider risks of fatalities.

Many implementation issues need to be addressed in order to develop credible contingent market applications for valuing changes in risks. One of the most important of these is the presentation of the change in risks to be valued. Numerical descriptions are probably not good enough. How many people actually know what the numerical risks are for the activities in which they engage? Other kinds of presentations need to be developed that link the risk levels to activities with which the respondent is familiar. All of the bias problems that have been found in previous contingent market applications need to be considered. Differences in the presentation of risk in the bidding or valuation procedure, in the hypothetical payment mechanism, in the order of the questions, and in other information provided to the respondent need to be systematically examined to see if responses are being biased by the survey instrument itself.

Another possibility for contingent market approaches would be to explore indirect valuation procedures such as contingent ranked attributes. In these procedures respondents are asked to rank alternatives without having to put a dollar value directly on risks. Their rankings reveal implicit valuations. Other possibilities would be to ask about willingness to spend time, rather than money, in order to decrease risks.

Other Research Topics

Some evidence has been provided by Litai (1980) and Starr (1969) that different risk types are valued differently. If the effects of these differences in risk types on willingness to pay were known, then the results from a study valuing one type of risk could be used to value other types of risks in environmental benefit studies. For example, at present it is not clear whether wage-risk studies, which reflect the most extensive work done to date on risk-dollar tradeoffs, provide any useful information for environmental policy questions due to the type of risks that were evaluated. Determining the transferability of risk valuation estimates could greatly improve the usefulness of past estimates in policy studies.

The work by Starr (1969) and Litai (1980) provides some initial ideas about how the nature and circumstances of the risk may affect willingness to pay. The Litai (1980) and Starr (1969) studies did not, however, adequately consider the benefits associated with the risks examined. As discussed in Section 5.3, it may be possible to use their data sets, or other similar data, along with better estimates of the benefits of incurring the different risks to obtain risk conversion factors based on benefit-cost ratios for risks with different characteristics. These could then be used to calculate meaningful risk conversion factors based on the Litai (1980) approach. For example, Starr's use of expenditures on cigarette smoking as the measure of the benefits of cigarette smoking greatly understate actual benefits as measured by consumer surplus. The result is that the benefit-cost ratios he uses to compare voluntary and involuntary risks may be badly biased. In most cases the biases in the benefits estimates seem to create an artificially large difference between voluntary and involuntary risks. The results of an approach that properly accounts for the benefits would be very informative. Whether the data are available to estimate the benefits of these activities with any accuracy is, however, somewhat uncertain.

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APPENDIX

ACTON STUDY QUESTIONNAIRE

WILLINGNESS-TO-PAY QUESTIONNAIRE

1. What do you think is the most important health problem in this country?

   ____

   ____

2. How would you rank these four health problems so that the first problem is the one you would like to see us work hardest on?

   Maternity and infant care ______
   Automobile accidents ______
   Heart disease ______
   Cancer ______

   (Place a "1" next to the most important item, a "2" next to the second most important, and so forth.)

3. Suppose two victims of an automobile accident arrive at a hospital at the same time. Both men are badly hurt and will probably die if not given a lot of medical care. Suppose that there are enough doctors and nurses there to be able to save one of the person's

lives but not both lives. All we know about the two men is their ages; we don't even know if they are married or if they have children. If you could make general public policy for cases like this, which do you think should be saved, a 60 year old man or a 20 year old man?

3a. (Circle your choice.) 60 20

Suppose the victims are a 40 year old man and a 20 year old man; which one do you think the doctors should save?

3b. 40 20

(CONTINUE ASKING THE SAME QUESTIONS FOR THE FOLLOWING PAIRS)

3c. etc.

30	20
30	25
40	30
50	40
60	50
70	65
70	10
40	10
20	10
10	5
20	5

4. What age or ages would you want to be saved above all others when only one person can be saved?____________________

5. Now suppose that more than two seriously injured persons are brought to the emergency room at once, and there are not enough doctors and nurses to care for all of them. Those who do not get care will almost certainly die. If you can save either two 70 year old men or one 30 year old man, which would you like them to save?

5a. TWO 70 ONE 30

(CONTINUE ASKING FOR THE FOLLOWING PAIRS)

5b. etc.

TWO 60	ONE 30
" 50	" 30
" 40	" 30
" 70	" 40
" 60	" 40
" 70	" 50

6. Now let's suppose that one man and one woman are brought in very badly hurt. Again, the doctors can save only one of them. We don't know if the man is a father or if the woman is a mother. Which do you think they should save, a 40 year old WOMAN or a 20 year old MAN?

6a. 40 WOMAN 20 MAN

(CONTINUE ASKING FOR THE FOLLOWING PAIRS)

6b. etc.

30 WOMAN	20 MAN
30 "	30 "
20 "	30 "
20 "	40 "

7. Have you heard about the new heart attack ambulances they are trying out in New York and a few other cities?

YES NO

8. They are thinking about putting ambulances and other devices in communities around the country, but only if people are willing to pay enough for them. This program would be for you and 10,000 people living around you. In your area, there are about 100 heart attacks per year. About 40 of these 100 persons die. With the heart attack program, only 20 of these people would die. How

much would you be willing to pay in taxes per year for the ambulance so that 20 lives could be saved in your community?

$____________________

9. There is a more economical program you could have (it has a different ambulance coverage and other features). Instead of saving 20 lives per year, it would save 10 lives. How much would you be willing to pay in taxes per year for this program so that 10 lives could be saved in your community?

$____________________

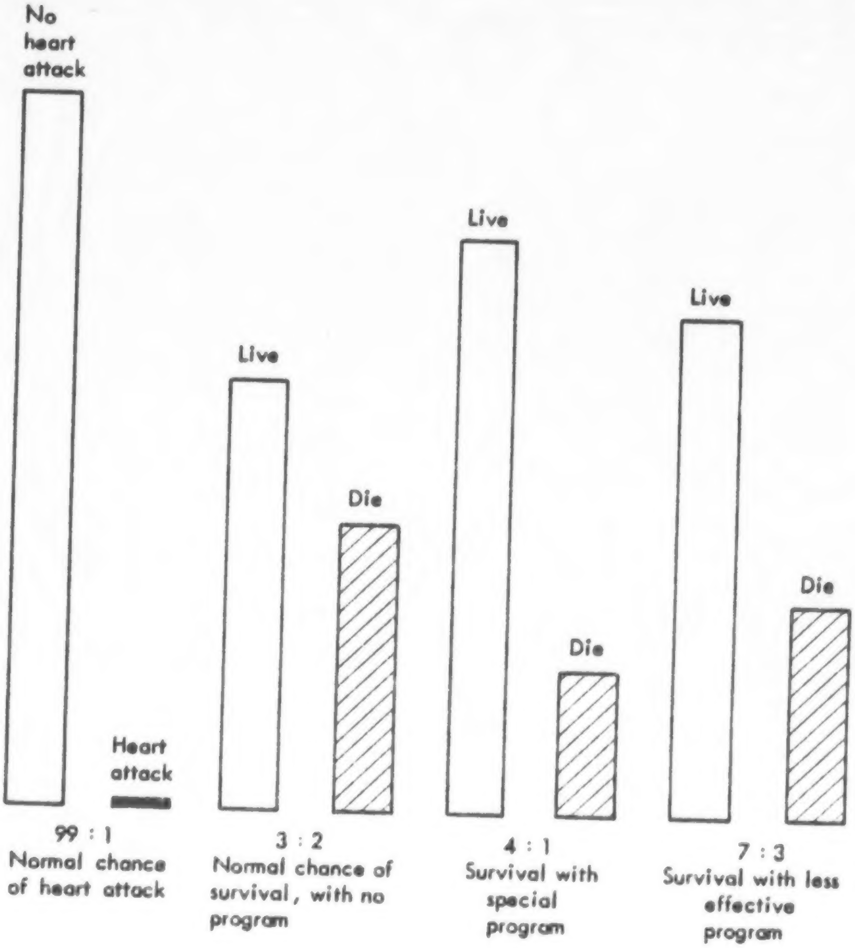
10. SEE CARD A Let's say that one of your neighbors comes to you for advice. He has just been to his doctor and the doctor tells him that there is one chance in 100 that he will have a heart attack in the next year. If he has the heart attack, the odds are 3 to 2 that he will live. Your neighbor has just heard about the heart attack program that can cut his chance of dying from the heart attack in half and he wants to know how much it is worth to him. How much do you think he should be willing to pay in taxes for a heart attack program in his neighborhood (i.e., the chances are 2 per 1,000 he will have a heart attack and be saved by the program this next year)?

$____________________

11. How much do you think he should be willing to pay for the less expensive program which is half as effective? That is, the odds would be 7 to 3 that he would live after a heart attack (i.e., the chances are 1 per 1,000 it will save his life).

$____________________

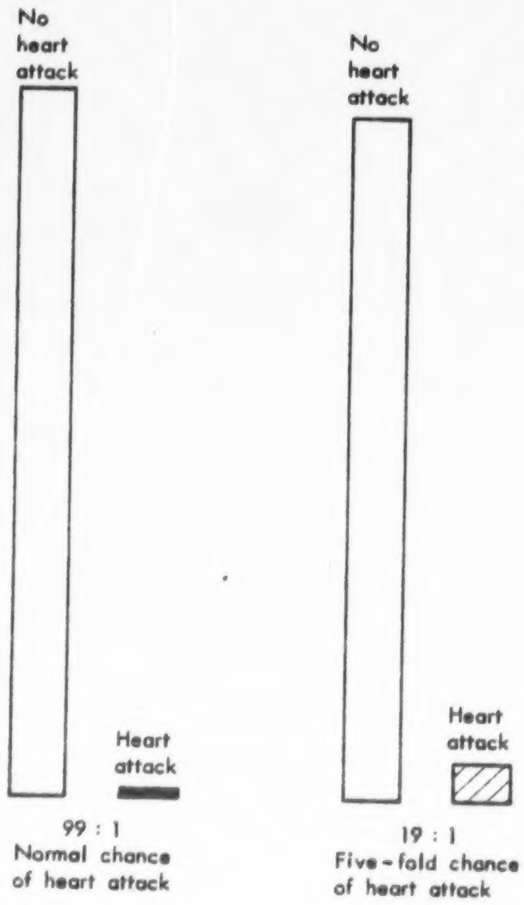
Card A



12. SEE CARD B Let's say that the doctor told your neighbor that he has five times the normal risk of a heart attack--that is, the odds are 1 to 19 that he will have a heart attack next year. If he could still cut his chance of dying from the heart attack in half, how much do you think he should be willing to pay in taxes for the heart attack program per year (i.e., the chances are 10 per 1,000 it will save his life)?

$____________________

Card B


No heart attack
Heart attack
99 : 1
Normal chance of heart attack
No heart attack
Heart attack
19 : 1
Five-fold chance of heart attack

13. How much do you think he should be willing to pay in taxes for the less expensive program which is half as effective (i.e., 5 per 1,000 it will save his life)?

$____________________

On the following questions, we ask your own willingness to pay for some of the heart attack programs. You should answer as if the stated probabilities are valid for you, and reductions in heart attack mortality are also valid. We can use a combination of ambulances, self-carried drugs, and other means to make certain that the reductions will be achieved even if you are away from your home community frequently.

As far as the amount, it pays for you to state the highest amount you are willing to pay. We will ask a number of persons how much they are willing to pay, and if we can cover the costs, the program will be established. If the program costs less than you said you were willing to pay, then you will be charged only actual costs; but if the cost is even $1 more than you say, you will not be covered and will have to wait until next year to be able to join again.

14. SEE CARD A

Let's suppose that your doctor tells you that the odds are 99 to 1 against your having a heart attack. If you have the attack, the odds are 3 to 2 that you will live. The heart attack program would mean that the odds are 4 to 1 that you live after a heart attack. How much are you willing to pay in taxes per year to have this heart attack program which would cut your probability of dying from a heart attack in half (i.e., the chances are 2 per 1,000 you will have a heart attack and be saved by the program this next year)?

$____________________

15. The less expensive program gives you 7 to 3 odds of living after a heart attack. How much are you willing to pay in taxes per year to have this program (i.e., 1 per 1,000 it will save your life)?

$____________________

16. Finally, let's suppose for some reason the doctor told you that your odds of having a heart attack are 1 to 19. If you could still cut your chance of dying in half, how much are you willing

to pay for the program which gives you odds of living if you have a heart attack (i.e., 10 per 1,000 it will save your life)?

$____________________

17. How much are you willing to pay for the less expensive program which gives you 7 to 3 odds of living if you get a heart attack (i.e., 5 per 1,000 it will save your life)?

$____________________

18. Suppose a local bond issue is proposed to pay for a heart attack program to serve you and your neighbors. If your household taxes were going to be raised $10 per year by this bond, how many lives (or fraction of a life) would you demand that it save per year to be worth $10? That is, if it will not save the number of lives you demand, then you will vote NO on the bond.

Smallest number of lives that must be saved to be worth $10 __________per year

19. What if the bond for the program will raise your taxes $20 per year. How many lives (or fraction) will you want it to save or else you vote NO?

Smallest number of lives that must be saved to be worth $20 __________per year

20. Now, what if the heart attack bond issue will raise your household's taxes $100 per year, what is the smallest number of lives (or fraction) you demand that it save per year or else you vote NO?

Smallest number of lives that must be saved to be worth $100 __________per year

21. Finally, suppose your neighbor comes to you for advice—but his question is a little different than it was before. He has been told that he has a 1 in 100 chance of a heart attack and can reduce his mortality from the heart attack from 2/5 to 1/5 (i.e., the chances are 2 per 1,000 that he will have a heart attack and have his life saved). He decides this program is worth $100 per year to him. His question is: how much should he pay for the program which is half as effective (i.e., the chances are 1 per 1,000 he will have a heart attack and have his life saved)?

$50
more than $50
less than $50

23. Suppose his is at a fivefold risk of heart attack and can cut his heart attack mortality from 2/5 to 1/5, how much should he pay (i.e., the chances are 10 per 1,000 he will have a heart attack and have his life saved by the program)?

$500
more than $500
less than $500

To make the study more complete, we need to know a few things about you and your family.

Sex: Male
Female

Age:

Are you: Married now = 1
Widowed or divorced = 2
Never married = 3

Are you the head of the household? Yes No

DEPENDENTS AND MEMBERS OF THE HOUSEHOLD

	age	living at home	
		YES	NO
Wife or husband	____	Y	N
Sons	____	Y	N
	____	Y	N
	____	Y	N
	____	Y	N
	____	Y	N
Daughters	____	Y	N
	____	Y	N
	____	Y	N
	____	Y	N
	____	Y	N
Parents	____	Y	N
	____	Y	N
Others (specify)	____	Y	N

How many years of schooling do you have?____________________

What is the highest degree you hold?

No degree = 1
H.S. Diploma = 2
Bachelor = 3
Master = 4
Ph.D. = 5
M.D. = 6
LLB = 7

If Bachelor's degree or higher, what was the subject of the degree?

Physical science = 1
Social science = 2
Arts or Humanities = 3
Economics = 4
Business = 5
Math or Statistics = 6

Do you rent or own your home?

Rent = 1
Own = 2

It may be important to know how people of different incomes answer these questions.

What was the combined income, before taxes, for you, your dependents, and those living with you per year?

$____________________

What is the approximate net worth of you, your household, and dependents? This should include your ownership of a home, a car, any saving or other assets; but you should subtract debts.

$____________________

It may be important to know how much people spend on medical care, so we would like to ask a few questions about your medical expenses.

About how much did you and members of your family living with you pay for medicine and visits to a doctor (not hospitalization) this last year? Please include any part paid by insurance.

$____________________

What part was paid by insurance? ____________________%

Did you or anyone in your family living with you go to the hospital this last year?

Yes________ No________

IF YES

Person (Relation)	Age	Reason*	About how much did this cost?	Part paid by insurance or other

* REASONS: An operation = 1
A heart condition = 2
Something else = 3

About how much do you and members of your family living with you spend on hospital insurance and doctor-payment insurance (like Blue Cross, Blue Shield, or a company policy)?

$___________________

About how much life insurance do the members of your family have? Please include any policies that the person may have through work or any other group.

Person	Age	Amount of Coverage

Would you rate your general health as excellent, good, fair, or poor?

EXCELLENT____ GOOD____ FAIR____ POOR____

Have you or anyone in your family living with you ever had any heart disease?

Self = 1
Other member = 2
No one = 3

JONES-LEE QUESTIONNAIRE

'VALUE OF SAFETY' QUESTIONNAIRE

1. Suppose that for various reasons you have decided to make a particular journey by air and have the choice of travelling on one of two airlines, A or B. These two airlines use the same type of aircraft and provide effectively identical services (same journey time, same route, same frequency of flights, similar food and in-flight facilities etc.)

   Airline A's fare is £100. Furthermore, airline A has a recent safety record of 2 fatal crashes in 500,000 flights.

   At what fare would you *just* be induced to fly by airline B rather than airline A if the recent safety record for airline B is:

   (a) 0 fatal crashes in 500,000 flights ______
   (b) 1 " " " " " ______
   (c) 5 " " " " " ______
   (d) 10 " " " " " ______
   (e) 20 " " " " " ______

   If in any instance you would not fly by airline B at any price then put 'X'.

   Assume that you are to be paid fixed expenses of £100 for the journey and that you will be unaccompanied by wife or other members of your family You should also assume that the recent crash record is the *only* available information concerning the safety of each airline.

2. Assuming that you would again be paid expenses of £100/journey, would your answers to question 1 be different if the journey was to be made once per week for one year? If the answer is 'yes', then indicate the modified fares in parentheses beside the answers to question 1. If the answer is 'no', then write 'no' here.

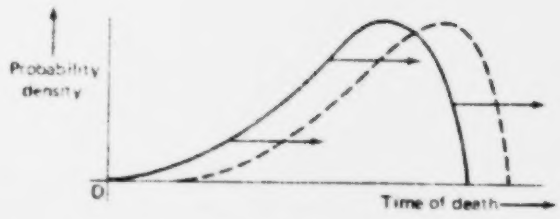
3. Suppose that you face a job location decision, the alternatives being areas A and B. (Assume that the option of remaining in your current location is not available.) Suppose further that considering all pros and cons *except* (a) house prices and (b) the impact of environmental pollution on life expectancy* you are indifferent between the two alternative locations.

   If area A has a 'normal' level of environmental pollution (so that your life expectancy will be as given by standard mortality tables), indicate the premium or discount on area B house prices relative to area A which would *just* induce you to choose area B if the environmental pollution for area B is such as to change your life expectancy by:

   (a) adding 1 year ______ / ______
   (b) adding 5 years ______ / ______
   (c) adding 10 years ______ / ______
   (d) subtracting 1 year ______ / ______
   (e) subtracting 5 years ______ / ______
   (f) subtracting 10 years ______ / ______

   Give one set of answers for the case in which the effect on life expectancy applies only to yourself and (if you have a family) one set for the case in which it applies both to yourself and your family. *Give premia and discounts in absolute amounts of money rather than as percentages.* Assume that you plan to remain in the new location for a sufficiently long time for any differential capital gains on house resale to be negligible (i.e. the premium or discount on current purchase price is to be an effective once-for-all lump sum gain or loss).

* An increase in life expectancy is an increase in the statistical mean age at death and will therefore inevitably affect the *entire* probability density function for time of death. In this case you may assume that there is negligible error in treating this as an effective rightward shift in the density function, i.e.



4. What is your current age?
5. What is your current salary?
6. What is your current occupation?

MULLIGAN STUDY QUESTIONNAIRE

INTRODUCTION

This survey will require your special attention. Although the situation being described is hypothetical, please answer the questions as if you were actually faced with the decision. You will be asked about your willingness to pay to avoid certain risks of death or injury to yourself resulting from a nuclear plant accident. You will also be asked about your willingness to receive money to permit these risks to occur. Please keep in mind that the risks being dealt with are only those that affect you, and not your community, friends, family etc.

A nuclear plant accident, in this case. would include any type of explosion, plus any other mishap, act of sabotage or war, or natural disaster which would cause large amounts of radioactive material to be released from the plant and into the environment. A serious injury would be any illness or injury resulting from the plant accident, which would require hospitalization in normal times. Also counted as injuries would be the long term aftereffects such as cancer, sterility, birth defects in children born after the accident, and a shortening of life expectancy.

THE GAME: PAYMENT FIRST

You will be asked whether you would pay or would receive money, for changes which would decrease or increase these risks. In the first case, you are being asked whether you would pay for a change which would lower these risks. We are not specifying what changes would be necessary, but examples might be changes in the nuclear plant itself, to changing to an entirely different energy system such as coal or solar energy. The method of payment for this change is an addition to your monthly energy bill. If your home is electrically heated, your monthly energy bill equals your electricity bill. If your home is heated any other way, your energy bill equals your electricity bill plus your monthly fuel bill. If you live in an apartment where your landlord pays for heating and utilities, the increase you would be paying would be an increase on your monthly rent. This would be the only means of payment available, and all people in the United States would pay a similar amount proportionate to their use of energy.

1. Please estimate your average monthly energy bill, it is not necessary to be exact.

The next several questions refer to changes in risk levels. Here is a graph representing those changes. If you like, refer to it with me as you answer the following questions.

PAYMENT QUESTIONS

2. Suppose that under a certain system of nuclear plant operation, accidents occured that killed or injured 200,000 people. Since there are 200,000,000 people in the United States, your (your child's) chance of being one of those affected would be 1 in 1,000. A change which would lower the number of people affected to 20,000 would also decrease your (your child's) risk from 1 in 1,000 to 1 in 10,000. What is the largest increase on your monthly energy bill that you would pay to cause this change, about $5? (Would you be willing to pay more, less, nothing?)

3. In order to further lower your (your child's) risk of being killed or injured from 1 in 10,000 to 1 in 100,000; or to lower the number of people affected from 20,000 to 2,000. What is the largest additional amount you would be willing to pay, another $5? (etc.)

4. To lower the risk further, from 1 in 100,000 to 1 in 1,000,000; or to decrease the number of people affected from 2,000 to 200, what is the largest addition you would be willing to pay?

5. To cause a change which would lower your (your child's) risk further from 1 in 1,000,000 to 1 in 10,000,000; or the number of people from 200 to 20, would you be willing to pay another $5?

6. Finally, for a change which would lower your (your child's) risk of being killed or injured in a nuclear plant accident from 1 in 10,000,000 to 1 in 100,000,000; and which would decrease the number of people affected from 20 to 2, how much of an addition would you be willing to pay on your average monthly energy bill?

7. (To the interviewer) What was the accumulative amount bid by the participant?

This time let us consider a different situation. Now you are asked to receive money to permit risk levels to increase. Some examples of this kind of change might be to permit weaker safety standards in nuclear plants, to locate plants nearer to areas of high population, or to permit more plants to be operated at the same time. The way in which you would receive this money would be through a reduction in your monthly energy bill, and all people in the United States would receive a similar amount of money proportionate to their energy use.

COMPENSATION QUESTIONS

8. Suppose that under a certain system of nuclear plant operation, accidents occured that killed or injured 2 people. Since there are 200,000,000 people in the United States, your (your child's) risk of being one of those affected would be 1 in 100,000,000. A change which would raise the number of people affected to 20 would also increase your (your child's) risk from 1 in 100,000,000 to 1 in 10,000,000. If you would permit this change what is the smallest amount of money you would be willing to receive as a reduction on your energy bill, $5?

9. In order to permit a further increase in your (your child's) risk of being killed or injured from 1 in 10,000,000 to 1 in 1,000,000, or to increase the number of people affected from 20 to 200, what is the smallest additional reduction on your energy bill that you would want to receive, another $5?

10. To permit the risk to rise further from 1 in 1,000,000 to 1 in 100,000; or to increase the number of people affected from 200 to 2,000, would you wise to receive an additional $5? (etc.)

11. For a change which would raise your (your child's) risk further from 1 in 100,000 to 1 in 10,000, or to increase the number of people affected from 2,000 to 20,000, what is the least additional amount that you want to receive?

12. Finally, for a change which would raise your (your child's) risk of being killed or injured in a nuclear plant accident from 1 in 10,000 to 1 in 1,000; and which would decrease the number of people affected from 20,000 to 200,000, what is the smallest additional decrease in your energy bill that you would accept?

13. (To the interviewer) What was the cumulative amount the participant was willing to accept?

INTRODUCTION: PARENTS

This survey will require your special attention. Although the situation being described is hypothetical, please answer the questions as if you were actually faced with the decision. You will be asked about your willingness to pay to avoid certain risks of death or injury to your child resulting from a nuclear plant accident. You will also be asked about your willingness to receive money to permit these risks to occur. Some of the effects of being in such an accident would not be felt for many years, particularly in the case of children. Therefore, please remember to include the costs that would occur over their entire lifetimes in your answers. Also, please remember that the risks being dealt with are only those that affect your child, and not you, your community, friends, other family members etc.

A nuclear plant accident, in this case, would include any type of explosion, plus any other mishap, act of sabotage or war, or natural disaster which would cause large amounts of radioactive material to be released from the plant and into the environment. A serious injury would be any illness or injury resulting from the plant accident, which would require hospitalization in normal times. Also counted as injuries would be the long term aftereffects such as cancer, sterility, birth defects in children born after the accident, and a shortening of life expectency.